Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion℠

February 29, 2008

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Serial No.	07-0797
NSSL/RWM	R1
Docket Nos.	50-336/50-423
License Nos.	DPR-65/NPF-49

DOMINION NUCLEAR CONNECTICUT, INC. MILLSTONE POWER STATION UNITS 2 AND 3 SUPPLEMENTAL INFORMATION OF CORRECTIVE ACTIONS IN RESPONSE TO NRC GENERIC LETTER 2004-02, POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

In letters dated March 4, September 1 and November 29, 2005, and in a letter dated November 15, 2007, Dominion Nuclear Connecticut, Inc. (DNC) submitted information in response to U.S. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors." This letter provides, herein, supplemental information associated with GL 2004-02 at Millstone Power Station Units 2 and 3 (MPS2 and MPS3). The content and level of detail in this letter's attachments conform to the recent guidance to the Nuclear Energy Institute from the NRC letter dated November 21, 2007, for preparation of a supplemental response to GL 2004-02 (Reference ADAMS Accession No. ML073110389).

If you have any questions or require additional information, please contact Mr. William D. Bartron at (860) 444-4301.

Sincerely,

Gerald T. Bischof
Vice President – Nuclear Engineering

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Gerald T. Bischof, who is Vice President – Nuclear Engineering, 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 29th day of February, 2008.

My Commission Expires: August 31, 2008.

MARGARET B. BENNETT
Notary Public 354302
Commonwealth of Virginia
My Commission Expires Aug 31, 2008

Margaret B. Bennett
Notary Public

A116
NRR

Commitments contained in this letter: None

Attachments: (2)

1. Millstone Unit No. 2, Generic Letter 2004-02 Supplemental Information
2. Millstone Unit No. 3, Generic Letter 2004-02 Supplemental Information

cc: U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, Pennsylvania 19406-1415

Ms. C. J. Sanders
NRC Project Manager Millstone Units 2 and 3
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O8 B3
11555 Rockville Pike
Rockville, MD 20852-2738

NRC Senior Resident Inspector
Millstone Power Station

ATTACHMENT 1

GENERIC LETTER 2004-02 SUPPLEMENTAL INFORMATION FOR MILLSTONE POWER STATION UNIT 2

DOMINION NUCLEAR CONNECTICUT, INC. (DNC)
MILLSTONE POWER STATION UNIT 2

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 2

1. DESCRIPTION OF APPROACH FOR OVERALL COMPLIANCE

Dominion Nuclear Connecticut, Inc. (DNC) is in full compliance with regulations and regulatory requirements that are listed in U.S. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," including acceptance criteria for Emergency Core Cooling Systems (ECCS), 10 CFR 50.46(b)5, Long-Term Cooling. Corrective actions related to GL 2004-02 resulted in plant changes that are supported by completed analyses for Millstone Power Station Unit 2 (MPS2). Corrective actions that continue to evaluate downstream and chemical effects analyses are still in progress, supporting the changes and modifications that have been made in response to GL 2004-02.

There is reasonable assurance that the MPS2 ECCS system can provide long-term cooling of the reactor core following a loss of coolant accident (LOCA). The ECCS system, including high pressure safety injection (HPSI), low pressure safety injection (LPSI), and containment spray systems (CSS) can remove decay heat so that the core temperature is maintained at an acceptably low value for the extended period of time required by the long-lived radioactivity remaining in the core. In addition, the CSS can operate to reduce the source term to meet the limits of 10 CFR Part 100.

A brief description of the approach taken to respond to GL 2004-02 is provided in the balance of this Section 1. The description includes information about methodology, modifications and their associated changes, and conservatisms. An overview of completed and in progress corrective actions is provided by Section 2 of this Attachment. Sections 3.A through 3.P provide more specific information regarding methodology and compliance.

A. METHODOLOGY OF ANALYSES:

The potential for adverse effects of post-accident debris blockage and debris-laden fluids to prevent the recirculation functions of the ECCS and CSS was evaluated for MPS2. The evaluation considered all postulated design basis accidents 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, as modified by the NRC Safety Evaluation (NRC SE), dated December 6, 2004.

- Break Selection
- Debris Characteristics
- Debris Transport
- Debris Generation and Zone of Influence
- Latent Debris
- Head Loss

Vortexing	Net Positive Suction Head Available
Debris Source Term	Structural Analysis
Upstream Effects	

Downstream effects (components) analysis is complete, consistent with the methodology of WCAP-16406-P, Draft Rev. 1 "Evaluation of Downstream Sump Debris Effects in Support of GSI [Generic Safety Issue]-191," May 2006. A revision to this analysis consistent with the NRC approved methodology in WCAP-16406-P, Rev. 1, August 2007, is in progress.

Downstream effects analyses for the fuel and vessel are in progress, consistent with the methodology of WCAP-16793-NP, Rev. 0 "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007.

Chemical effects analyses are being performed that use a thorough assessment of existing literature and test data in conjunction with bench scale and reduced scale plant-specific testing.

Coatings are analyzed using a radius of 5-pipe diameters (5D) assigned to the Zone of Influence (ZOI) as detailed in Section 3.H for resolution of chemical effects and downstream effects. New strainer sizing and head loss testing was completed using qualified coatings ZOI of 10D. All coatings were assumed to be 10-micrometer particulate consistent with the GR and NRC SE.

B. MODIFICATIONS AND CHANGES:

The following plant modifications were installed.

- A new 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 has been designed to withstand up to approximately 1 atmosphere (atm) of differential pressure and it has a strainer hole size of 1/16 inches, which is smaller than previous screen hole size of 3/32 inches.
- Calcium silicate insulation was removed from piping and equipment in containment such that no calcium silicate insulation could be part of the ECCS strainer debris bed for any break that would require recirculation. All 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.

The following changes were also made.

- Containment cleanliness standards have been defined and detailed in a station housekeeping procedure.
- Design controls have been put in place to require evaluation of potential debris sources in containment created by or adversely affected by design changes.
- 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.

C. CONSERVATIVISMS:

Detailed analyses of debris generation and debris transport were performed to ensure that a bounding quantity and mix of debris arrived at the strainer. Using the results of these analyses, conservative head loss testing was performed in both reduced-scale and large-scale test tanks to determine worst-case strainer head loss. A conservative basis is incorporated into the analyses, as discussed by items in the balance of this section.

- Debris generation analysis uses very conservative ZOIs that result in the removal of virtually all insulation within the affected loop room. Conservative ZOIs from NEI 04-07 were applied, which did not differentiate between insulation that was jacketed with stainless steel and the insulation that was jacketed only with canvas covering. 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.
- There are numerous surfaces throughout containment where insulation and other debris is likely to settle following break blowdown and not be dislodged by washdown or containment spray, and thus the debris is not 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.
- Although credit is taken in the design of the strainer for leak-before-break in consideration of pipe whip, jet impingement or 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 MPS2 licensing basis that reduces the size of the break that 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.

- All unqualified coatings in containment are assumed to fail as transportable particulate.

- 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.

- 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.

- No credit was taken for accident-induced overpressure in calculation of net positive suction head (NPSH) margin for the ECCS pumps.

- 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 which have extremely low velocities during recirculation as shown in the computational fluid dynamics (CFD) analysis.

- The replacement strainer has two legs of strainer modules that results in a strainer footprint spread over a very large region of containment. For any one break in containment, the break-induced turbulence in the post-LOCA sump pool would be localized. The large strainer footprint combined with the localized turbulence results in large areas of the containment sump pool having 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.

Additional conservatisms:

- 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

- 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.

- 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.

D. SUMMARY:

Based on the methodology, modifications, and conservatisms described above, there is a high confidence that the issues identified in GL 2004-02 have been addressed even with the uncertainties remaining (i.e., downstream effects analyses and chemical effects analyses).

2. GENERAL DESCRIPTION AND SCHEDULE FOR CORRECTIVE ACTIONS

The DNC letter dated November 15, 2007, provided a schedule and requested an extension beyond December 31, 2007, to complete GL 2004-02 corrective action milestones that are associated with the performance of further chemical effects and downstream effects analyses. Completed corrective actions are summarized in Table 2-1. Corrective actions in progress are summarized in Table 2-2.

Table 2-1: Completed Corrective Action Overview

Debris Generation and Debris Transport Analyses

Contains:

- break selection criteria,
- calculation of amount and type of debris generated for limiting breaks,
- breakdown of debris sizes,
- physical debris characteristics (i.e., density, fiber size, particulate size), and
- calculation of amounts of each debris postulated to reach the ECCS strainer.

Analysis of Clogging and Wear for Components in ECCS Flow Stream Downstream of ECCS Strainer

These analyses use methodology in WCAP-16406, Draft Rev. 1 and include:

- list of components susceptible to clogging which are in the ECCS flowpath downstream of the ECCS strainer,
- demonstration of clogging potential, and
- calculation of wear potential for susceptible components based on postulated debris bypass (i.e., all particulate is assumed to pass through the strainer for the component wear analysis).

Analyses of Water Holdup in Containment

Locations are identified where water will be blocked from reaching the ECCS strainer. Analyses for water holdup includes:

- holdup on component surface areas in containment,
- holdup on floors throughout containment, and
- holdup of water in atmosphere.

Replacement ECCS Strainer Modification

The ECCS strainer modification is currently installed. The new strainer has the following characteristics:

- surface area is approximately 6120 ft^2 versus original strainer surface area of approximately 110 ft^2,
- finned strainer was designed and manufactured by Atomic Energy of Canada Limited (AECL),
- strainer is fully submerged prior to recirculation.

Calcium Silicate Insulation Removal

Calcium Silicate insulation has been removed from piping and equipment that could be impacted by a break requiring ECCS recirculation.

Table 2-1: Completed Corrective Action Overview

Chemical Precipitate Analysis and Effects
Analysis of chemical precipitate formation and effects of those precipitates on ECCS strainer clogging is completed. This effort included the following: • data review of WCAP-16530-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007, • review of Integrated Chemical Effects Test (ICET) Reports, • review of open literature data on aluminum corrosion and solubility, and • comparison of test data to MPS2 expected post-LOCA plant conditions

Table 2-2: In Progress Corrective Action Overview

Downstream Effects Analysis
An evaluation of downstream clogging and wear was completed for MPS2 in accordance with WCAP-16406-P, Rev. 0 and Draft Rev. 1. However, WCAP-16406-P Rev. 1, was submitted in September 2007 and includes revised guidance for the performance of downstream effects evaluations for components, including the reactor vessel and nuclear fuel. Also, WCAP-16793-NP Rev. 0, issued in May 2007, provides guidance on evaluation of blockage and chemical precipitate plateout in the reactor core and fuel and is currently undergoing NRC review and Safety Evaluation Report preparation. Consequently, revised downstream effects evaluations must be performed in accordance with the most recent WCAP guidance. The revised downstream effects evaluations are scheduled to be complete as soon as practical, commensurate with expedited corrective actions. (The estimate for this activity to be complete is by the end of the first quarter of 2008).
Chemical Effects Analysis
A chemical effects evaluation is in progress for MPS2 by the strainer vendor, AECL, to determine the potential for chemical precipitate formation, and bench top testing is being performed to validate evaluation assumptions. Reduced scale testing for chemical effects may also be necessary based on the results of bench top testing and/or other industry/regulatory testing results. Completion of the required chemical effects evaluation and testing is required to confirm that the replacement strainer installed at MPS2 is adequate to maintain net positive suction head (NPSH) margin for the ECCS pumps during long-term core cooling and to confirm that no further physical modifications are required. Completion of the chemical effects evaluation and testing and issuance of the technical report will be completed as soon as practical, commensurate with expedited corrective actions. (The current estimate for this activity's schedule is being expedited to achieve a May 31, 2008 completion date).

3. SPECIFIC INFORMATION REGARDING METHODOLOGY FOR DEMONSTRATING COMPLIANCE

A. BREAK SELECTION:

Break selection identified the break size and location that presents the greatest challenge to post-accident sump performance using the NEI 04-07 GR, as supplemented by the NRC SE. The primary criterion used to define the most challenging break is the effect of generated debris on the estimated head loss across the sump screen. Therefore, all phases of the accident scenario were considered for each postulated break location: debris generation, debris transport, debris accumulation, and resultant sump screen head loss. Two attributes of break selection that are emphasized in the approved evaluation methodology cited above, and which can contribute significantly to head loss are: (1) the maximum amount of debris transported to the screen; and (2) the worst combinations of debris mixes transported to and onto the screen surfaces. Additionally, the approved methodology states that breaks should be considered in each high-pressure system that relies on recirculation. For MPS2 secondary side system piping does not require recirculation and so is excluded from consideration of limiting breaks.

The MPS2 GL 2004-02 Response Audit Report (ADAMS Accession No. ML072290550) contains a detailed description of break selection. The NRC reviewed the break selection methodology and results for MPS2 and found it acceptable with the exception of Open Item 1 from the audit that is discussed below. The conclusions in the GL 2004-02 Response Audit Report remain correct.

Open Item 1 from the audit is to confirm that the “loop seal pipe” piping arrangement does not result in a new limiting case for Break Criterion Case 3.

This open item consisted of two concerns. The first concern is that the location of the cold leg piping between the #2 steam generator and either of the loop 2 reactor coolant pumps could allow a direct path to the strainer for debris, with few or no intervening structures (e.g., grating), and that this may be a limiting break due to proximity to the strainer. The second concern is that no evaluation was done of pipe whip and jet impingement effects of this piping on the replacement strainer.

The breaks evaluated for debris generation included hot leg breaks in both loops where the hot leg connects to the steam generator nozzle. This break produces the largest quantity of insulation and the worst mix of insulation. Also evaluated was a break at the discharge of the loop 2A reactor coolant pump that would have a direct path to the sump since it is directly above part of the replacement strainer. The breaks at the hot leg steam generator nozzle produced a greater or equal quantity of each type of insulation existing in the MPS2 containment loop rooms than the break at the discharge of reactor coolant pump (RCP) 2A. Thus, the breaks at the hot leg steam generator nozzle are limiting both in quantity of debris produced and in worst-case mixture of debris produced. Debris produced by a break of the cold leg piping between the loop 2 steam generator and either of the loop 2 reactor coolant pumps would produce less insulation debris and could not result in a worse mix of insulation debris than the limiting hot leg nozzle break. While debris from this break would likely have a more direct path to the sump or to portions of the strainer, the debris transport calculation conservatively assumes that all of the generated debris arrives at the containment floor and that approximately 65% of the fibrous debris (and 100% of the particulate debris) arrives at the strainer surface. The conservatism in the debris transport calculation ensures that the ease of transport from a break to the strainer is not a factor in determining the amount of debris which arrives at the strainer and because of this, the limiting breaks analyzed are bounding.

Pipe whip and jet impingement concerns are not applicable to the reactor coolant piping because the MPS2 licensing basis includes approved leak-before-break analysis. Consistent with General Design Criteria 4 (GDC 4), the dynamic effects associated with pipe ruptures in the analyzed piping, including the effects of pipe whipping and discharge of fluids have been excluded from the design basis.

B. DEBRIS GENERATION / ZONE OF INFLUENCE (EXCLUDING COATINGS):

The objective of the debris generation/ ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; (2) the amount of debris generated by the break jet forces; and (3) the size characteristics of the debris. MPS2 followed the methodology described in Sections 3.4 and 4.2.2 of NEI 04-07 and the NRC safety evaluation (SE), which provide the methodology to be considered in the ZOI and debris generation analytical process. The MPS2 GL 2004-02 Response Audit Report contains a detailed description of debris generation and ZOI. The NRC reviewed the debris generation and ZOI methodology and results for MPS2 and found it acceptable with the exception of Open Item 2 from the audit that is discussed below. The conclusions in the GL 2004-02 Response Audit Report remain correct.

Open Item 2 is the finalization of the MPS2 debris generation calculation. The debris generation calculation, GSI-191-ECCS-04161M2 Rev. 1, has been finalized to eliminate calcium silicate insulation which is not part of the debris load for any limiting break and to remove debris generated by submergence and containment spray erosion since all of the insulation remaining in the LOCA ZOIs has sufficient covering to preclude significant debris generation by erosion and similar processes. Table 3.2-2 of the MPS2 GL 2004-02 Response Audit Report lists debris generation quantities. After the January 2007 NRC audit, the margin on fiberglass insulation has been reduced from 5% margin to 2% margin. Replacement of calcium silicate insulation in the ZOI with NUKON™ insulation has increased the amount of NUKON™ insulation generated by the worst case large break LOCA (LBLOCA). The margin of fibrous insulation generated was reduced in the debris generation calculation to ensure that the amount of fibrous debris analyzed to transport to the strainer did not exceed the amount used in the strainer design and testing.

C. DEBRIS CHARACTERISTICS:

The specification of debris characteristics is important to analytical transport and head loss evaluations and to the specification of surrogate materials for head loss testing. The potential LOCA-generated sources of debris for the MPS2 containment include debris from five types of insulation: NUKON™, Claremont fiberglass, mineral fiber, Transco encapsulated mineral wool, and Transco Reflective Metallic Insulation (RMI). Besides the insulation sources, other potential debris sources include latent fiber, latent particulate, foreign material debris, and coatings debris. The MPS2 GL 2004-02 Response Audit Report contains a detailed description of debris characteristics specific to MPS2. The NRC reviewed the debris characteristics for MPS2 and found it acceptable. The conclusions in the GL 2004-02 Response Audit Report remain correct.

D. LATENT DEBRIS:

MPS2 performed an evaluation of the potential sources of latent debris, using guidance provided by the NEI 04-07 and the NRC Safety Evaluation Report (SER). Latent debris is that debris that is present in containment before a postulated LOCA occurs, as opposed to debris that would be generated during a LOCA. Such debris could include fibers, particulates (e.g., dust and dirt), and tags and labels. NEI 04-07 provides recommendations for quantifying the mass and characteristics of latent debris inside containment. The following baseline approach is recommended: (1) estimate the total area, including both horizontal and vertical area contributions, (2) survey/sample the containment to determine the mass of debris present, (3) define the debris composition and physical properties, (4) determine the fraction of total area that is susceptible to debris buildup, and (5) calculate the total quantity and composition of debris. The MPS2 GL 2004-02 Response Audit Report contains a detailed description of latent debris. The NRC reviewed the method used for quantifying latent debris at MPS2 and found it acceptable. The conclusions in the GL 2004-02 Response Audit Report remain correct.

E. DEBRIS TRANSPORT:

Debris transport is conservatively analyzed for MPS2 consistent with the methodology in NEI 04-07 as approved by the NRC staff SER. The details of the debris transport analysis are contained in an evaluation addressing post-LOCA debris transport, head loss across containment sump screen, and NPSH. The MPS2 GL 2004-02 Response Audit Report contains a detailed description of the debris transport evaluation. The NRC reviewed the method used for analyzing debris transport and found it acceptable with the exception of Open Item 3 from the audit that is discussed below. The conclusions in the GL 2004-02 Response Audit Report remain correct.

The debris transport calculation has been revised since the January 2007 NRC audit to account for the reduction in qualified coatings that are generated (and assumed to transport) due to use of a 5D ZOI for coatings transport. These reduced particulate loads on the strainer debris bed were not used for strainer design but may be used for resolution of chemical effects and downstream effects.

The revised debris loads transported to the strainer are summarized in the tables below.

Table E-1: Debris Transport Calculation Results for CFD Scenario 1 (Break S3)

Debris Type	Transport Fraction	Quantity Transported
Claremont Fiberglass	0.65	47.3 ft^3
NUKON™ Fiberglass	0.65	644.8 ft^3
Mineral Fiber	1.0	244.1 ft^3
Mineral Wool	1.0	159.4 ft^3
Margin for Fiberglass	0.65	19.1 ft^3
Qualified Coatings	1.0	4.2 ft^3
Unqualified Coatings	1.0	8.8 ft^3
Margin for Coatings	1.0	1.3 ft^3
Latent Fiber	1.0	30 lb_m
Latent Particulate	1.0	170 lb_m
Foreign Material Allowance	1.0	150 ft^2
Transco RMI Foils	1.0	621.7 ft^2
Margin for Transco RMI Foils	1.0	31.1 ft^2

Table E-2: Debris Transport Calculation Results for CFD Scenario 2 (Break S1)

Debris Type	Transport Fraction	Quantity Transported
Claremont Fiberglass	0.59	94.3 ft^3
NUKON™ Fiberglass	0.59	669.7 ft^3
Mineral Fiber	1.0	297.3 ft^3
Mineral Wool	1.0	159.4 ft^3
Margin for Fiberglass	0.59	20.7 ft^3
Qualified Coatings	1.0	11.1 ft^3
Unqualified Coatings	1.0	8.8 ft^3
Margin for Coatings	1.0	2.0 ft^3
Latent Fiber	1.0	30 lb_m
Latent Particulate	1.0	170 lb_m
Foreign Material Allowance	1.0	150 ft^2
Transco RMI Foils	0.75	885.5 ft^2
Margin for Transco RMI Foils	0.75	44.3 ft^2

Table E-3: Debris Transport Calculation Results for CFD Scenario 3 (Break S2)

Debris Type	Transport Fraction	Quantity Transported
Claremont Fiberglass	0.65	103.9 ft^3
NUKON™ Fiberglass	0.65	748.8 ft^3
Mineral Fiber	1.0	297.3 ft^3
Mineral Wool	1.0	159.4 ft^3
Margin for Fiberglass	0.65	23.0 ft^3
Qualified Coatings	1.0	10.5 ft^3
Unqualified Coatings	1.0	8.8 ft^3
Margin for Coatings	1.0	1.9 ft^3
Latent Fiber	1.0	30 lb_m
Latent Particulate	1.0	170 lb_m
Foreign Material Allowance	1.0	150 ft^2
Transco RMI Foils	1.0	1385.4 ft^2
Margin for Transco RMI Foils	1.0	69.3 ft^2

Table E-4: Debris Transport Calculation Results for CFD Scenario 4 (Break S3)

Debris Type	Transport Fraction	Quantity Transported
Claremont Fiberglass	0.65	47.3 ft^3
NUKON™ Fiberglass	0.65	644.8 ft^3
Mineral Fiber	1.0	244.1 ft^3
Mineral Wool	1.0	159.4 ft^3
Margin for Fiberglass	0.65	19.1 ft^3
Qualified Coatings	1.0	4.2 ft^3
Unqualified Coatings	1.0	8.8 ft^3
Margin for Coatings	1.0	1.3 ft^3
Latent Fiber	1.0	30 lb_m
Latent Particulate	1.0	170 lb_m
Foreign Material Allowance	1.0	150 ft^2
Transco RMI Foils	1.0	621.7 ft^2
Margin for Transco RMI Foils	1.0	31.1 ft^2

Open Item 3 is to evaluate the potentially adverse effects of break flow drainage turbulence with respect to the replacement strainer.

Because the replacement strainers extend under the loop 2 piping (beyond the original strainer footprint), there is a potential for break flows to impact the sump pool near a portion of the strainer during recirculation. There are three potentially adverse effects requiring evaluation as a result of the potential. They are:

- Debris bed filtration impact and inhibited debris bed formation that creates clean strainer surface areas;
- Air ingestion due to turbulence and splashing from the break flow; and,
- Increased debris transport due to break flow turbulence around a portion of the strainer.

Debris Bed Filtration Impact and Inhibited Debris Bed Formation That Creates Clean Strainer Surface Areas:

The potential benefit from turbulence preventing debris bed formation is that clean strainer surface areas reduce strainer head loss since water flow is unimpeded by a debris bed. The breaks in loop 2 are considered generally likely to be in the vicinity of one of the two legs of the strainer. Prevention of debris bed formation would significantly lower head loss due to thin-bed formation and chemical precipitates mixed in with a thin-bed. However, inhibition of debris bed formation is not credited for this analysis because breaks in loop 1 piping are considered remote from either leg of the strainer and no testing has been done to quantify how far away the turbulence would be before debris bed formation is not inhibited.

The potential adverse effect from turbulence preventing debris bed formation is that clean strainer area will allow passage of all debris that can potentially fit through the strainer openings, which are 1/16" diameter circular holes. With clean strainer area, there is likely to be very little pressure drop across the strainer. This would inhibit debris that is larger than the hole size from being pulled through the holes. However, this effect may be offset by an increased velocity through an area of open strainer area and is not quantifiable since the area of clean or relatively clean surface area is not known.

Particulate debris would be able to pass easily through a clean strainer area since the coating and other particulate is generally considered to be much smaller than the strainer hole size. Though filtering of particulate would be reduced as a result of clean strainer area, the surface area of clean strainer is likely to be very small in comparison to the entire strainer surface area. Turbulence created by break flow could be effective locally at keeping a small part of the strainer surface area clean but would not likely impact the filtering of debris by the remainder of the strainer.

CFD analysis clearly shows that break flows are the major drivers of flow velocity in containment. Break flows near one part of the strainer are necessarily remote from much of the strainer and velocity of water in containment is relatively high near the break flow but tends to drop sharply away from the break flows. The large parts of containment with very low velocity reduce the potential for debris transport. Formation of a debris bed on portions of the strainer remote from the break flow (which comprises the vast majority of the strainer surface area for any particular break) will promote filtering. It is, therefore, reasonably conservative to have assumed a low level of particulate filtering in the downstream wear calculation.

Air Ingestion Due to Surface Disturbance and Turbulence Near Part of the Strainer:

The strainer is completely submerged prior to drawing suction through the strainer. The turbulence and surface disturbance that could occur near part of the strainer will tend to aerate the water in the containment pool. However, the containment sprays, which run during injection and during part of long-term recirculation, also significantly aerate the water. The Millstone evaluation of air ingestion (contained in the transport calculation) assumed the water to be saturated with air and determined that the resulting air coming out of solution would not exceed 2% at the ECCS pump suction or 3% inside the strainer. In addition, the MPS2 sump strainer is submerged by at least 6 inches at the start of recirculation. Turbulence and surface disturbances will not add more air to the water than is already assumed. The water seal over the strainer is unlikely to be breached by break flows near the strainer due to the submergence of the strainer at the conservatively calculated minimum water level that results in at least 6-inches of strainer submergence. The minimum submergence of the strainer by design was determined using a minimum water level of 4.23 feet. The minimum water level has been subsequently recalculated to be 5.6 feet for a LBLOCA (and 4.5 feet for a small break LOCA). Thus, actual submergence of the strainer will be greater than 6 inches upon initiation of recirculation. Of note, the small break LOCA (SBLOCA) will produce significantly less turbulence than a LBLOCA. Thus, air ingestion will not increase as a result of turbulence from break flows near a portion of the strainer.

Increased Debris Transport due to Break Flow Turbulence Around a Portion of the Strainer:

MPS2 RCS piping and ECCS strainer layout is such that a break in RCS piping directly above a portion of the strainer has the potential to drop a significant quantity of debris near the strainer. However, the containment is designed to direct the release of break energy upwards in containment which will tend to disperse debris throughout containment. The debris transport calculation contains significant conservatisms in that it assumes that all of the debris is deposited in the containment sump pool and that approximately 65% of the fibrous debris either transports to the strainer directly as fines or erodes into fines and transports to the strainer. The remaining approximately 35% of the fiber debris is assumed to be dislodged from the piping as intact pieces which are not subject to erosion. Some of these large pieces could land near or on the strainer and could end up between fins, but would not be able to lift onto the strainer from the floor due to relatively low velocities. Due to the significant conservatisms in the way debris erosion is treated and in the way transport is treated, there is no potential for increased debris transport (beyond what is determined in the debris transport calculation) to the strainer due to turbulence in the vicinity of a portion of the strainer. The turbulence on the surface of the water will not lift intact pieces of fibrous insulation, which are on the floor, up onto the strainer through the 4-foot water column. Additionally, the turbulence from break flows is near only a relatively small portion of the strainer and the CFD analysis shows that velocities drop off sharply away from the break flows. A break in loop 2 that is above one leg of the strainer does not produce significant velocities near the other leg of the strainer and, thus, transport would only be locally affected. Any actual increase in debris transport is bounded by the conservatisms in the debris transport calculation.

F. HEAD LOSS AND VORTEXING:

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

The MPS2 GL 2004-02 Response Audit Report contains a detailed description of head loss and vortexing. The NRC reviewed the method used for determining head loss and testing for vortex formation for the strainer and found it acceptable with the exception of Open Item 4 from the audit, which is further discussed in the last item of this Section F. The conclusions in the GL 2004-02 Response Audit Report remain correct.

A schematic diagram of ECCS and CSS is included in Figure F-1 at the end of this section.

Head Loss and Vortexing Analysis Overview:

Head Loss and the potential for vortexing were determined during head loss testing conducted at AECL facilities in Chalk River Ontario. Head loss was determined analytically using the correlation in NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," October 1995, and then design debris bed head loss was determined via testing. Strainer design (surface area and fin pitch) was determined in a series of reduced scale head loss tests, which tested both thin-bed and full debris loads. Strainer sizing was confirmed in large-scale tests using both thin-bed and full debris loads for determination of head loss. Strainer testing included tests to show that vortexing does not occur at maximum flow rates and minimum strainer submergence.

Test Scaling, Parameters and Debris Bed / Thin Bed Observation:

Test results were scaled from the test tank temperature of 104°F to the containment water temperature at the start of recirculation (bounded by 210°F). This scaling was done using viscosity and temperature, which was reviewed during the MPS2 audit. Testing in both the reduced-scale test tank and large scale test tanks exhibited some evidence of debris bed cracking and repair (boreholes). This was seen in periodic drops and recovery in the differential pressure across the debris bed. However, no tests were terminated prior to repair of these debris bed cracks as evidenced by the subsequent recovery in differential pressure. No evidence of this phenomena occurred in the thin-bed tests in either the reduced scale or large scale test tanks. Thus, scaling of the test tank results using viscosity is not affected by formation of boreholes.

Assessment of Debris Generation and Transport Analysis on Head Loss Margin:

The debris generation and transport calculations have been revised as discussed in Sections E and H to reduce the amounts of qualified coating postulated to be generated and transported to the strainer. Since the strainer was sized using the original coatings load that is detailed in the MPS2 GL 2004-02 Response Audit Report, the reduction in coatings provide a significant head loss margin.

The near-field effect is not credited for reducing the amount of debris transported to the strainer for MPS2. This is both reasonable and conservative because settling of debris during testing was prevented by the stirring of test tank water and periodic sweeping of the large scale test tank. This had the effect of maximizing the amount of debris suspended in the water with the ability to deposit on the strainer surface.

Buoyant debris could be generated by a LOCA. This debris is elastomeric foam. This debris will float and not absorb water. Consequently the buoyant debris will not create a strainer blockage concern and is not included in the debris generation calculation. No testing has been done to determine if this debris could collect on top of the strainer and create an air ingestion path through the strainer. However, creation of an air ingestion path is not credible due to the following;

- the minimum 6-inch submergence of the strainer,
- the minimal encapsulation of the strainer assuming all of the debris arrived at the strainer (nominally 3.5 inches), and
- because this debris floats on top of the water and will not be drawn down into the debris bed.

Flashing, Submergence, and Related Parameters:

The minimum water level for a SBLOCA is 4.5 feet above the floor and for a LBLOCA, minimum water level is 5.6 feet above the floor. Nominal strainer height at MPS2 is 45 inches above the floor.

The minimum strainer submergence for a SBLOCA is 9 inches and for a LBLOCA, minimum submergence is 1.8 feet. The minimum submergence for a LBLOCA exceeds the maximum pressure drop across the strainer with the worst-case debris bed (1.03 feet) assuming a saturated containment sump pool.

For a SBLOCA, submergence is adequate and flashing will not occur because:

- the strainer is unlikely to be completely covered with debris,
- the maximum debris head loss is dependent on the particulate load for a LBLOCA that would not occur for a SBLOCA,
- No containment accident pressure is credited in evaluating whether flashing would occur across the strainer surface.

- the actual maximum temperature of the sump water at the beginning of recirculation is 207°F (somewhat subcooled), and
- a debris bed takes significant time (hours) to form during which time the sump water will become further subcooled, adding NPSH margin for the ECCS pumps.

Potential for Reduced Sump Performance Analysis from a Single Failure (Audit Item):

GL 2004-02 Response Audit Report Open Item 4 relates to the evaluation and resolution of the potential for reduced pump NPSH margins and other adverse effects on sump performance analysis that may result from a single failure of a Low Pressure Safety Injection (LPSI) pump to trip following the receipt of a sump recirculation actuation signal (SRAS).

The maximum flow for strainer head loss testing was 6800 gpm. During injection following a LBLOCA, both High Pressure Safety Injection (HPSI) and LPSI pumps (as well as Containment Spray (CS) pumps) run. The LPSI pumps are designed to stop on SRAS (start of recirculation). The maximum flow at the start of sump recirculation is approximately 4700 gpm, assuming two trains operating each with a HPSI pump and a CS pump operating. Maximum flow is approximately 700 gpm for a HPSI pump, and approximately 1650 gpm for a CS pump.

The audit item 4 postulates that if a LPSI pump failed to stop on SRAS, total flow through the sump strainer could be approximately 9200 gpm. This increased flow could lead to a higher than tested head loss across the strainer. The maximum flow through the strainer is based on simultaneous hot leg and cold leg recirculation where one LPSI pump is injecting to the cold leg and a HPSI pump is injecting to the hot leg.

The DNC evaluation of the potential failure for a LPSI pump to stop on SRAS showed that this is a possible single failure. As a result, to ensure that flows through the strainer do not exceed 6800 gpm for any significant length of time, a change has been made to the MPS2 Emergency Operating Procedures (EOPs) to close LPSI injection valves upon identification that the LPSI pump failed to stop on SRAS. This will ensure that the flow through the strainer is equal to or less than the maximum flow of 6800 gpm.

Closing the LPSI injection valves upon identification that the LPSI pump failed to stop on SRAS can be done in a relatively short amount of time. The time to build a debris bed on a strainer has been shown in extensive head loss testing to be several hours, even with the debris deposited immediately adjacent to the strainer. Thus, it is acceptable to close LPSI injection valves to mitigate the single failure of a LPSI pump to stop on SRAS.

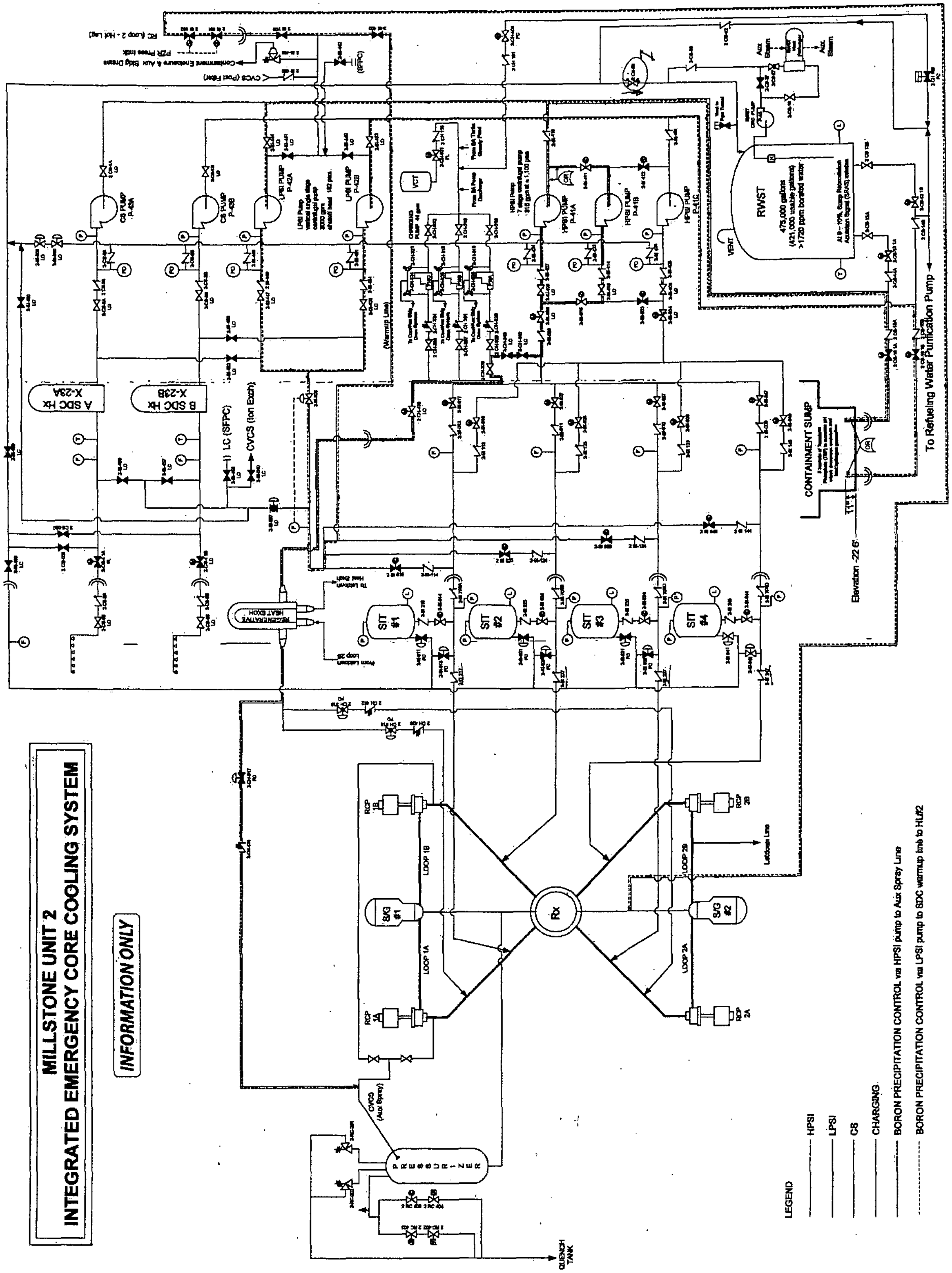


FIGURE F-1: Schematic Diagram of the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS)

G. NET POSITIVE SUCTION HEAD (NPSH):

NPSH margin is determined for the ECCS pumps using a comprehensive hydraulic model of the ECCS system. This calculation models all of the limiting ECCS flow and single failure combinations to determine the minimum NPSH margin for each pump. For conservatism, the sump water is considered saturated so that no credit is taken for sump water subcooling. Sump water subcooling increases with time after the accident during recirculation and adds considerable margin to the ECCS pumps' NPSH even while the debris bed is forming.

The MPS2 GL 2004-02 Response Audit Report contains a detailed description and evaluation of NPSH for the ECCS pumps. The NRC reviewed the method used for determining NPSH and found it acceptable with exception of Open Items 5, 6, and 7 from the audit that are discussed in the balance of this section. The conclusions in the GL 2004-02 Response Audit Report remain correct.

HPSI Pump NPSH Margin (Audit Item):

GL 2004-02 Response Audit Report Open Item 5 discusses the need to resolve a discrepancy in the calculation of HPSI pump NPSH margin. The ECCS hydraulic model has since been revised and now shows a limiting HPSI pump NPSH margin of 1.05 feet.

This limiting NPSH occurs for a non-degraded HPSI pump with a single failure of a diesel generator and atmospheric pressure in containment. The maximum strainer pressure drop due to a debris bed is 0.94 feet, and the maximum clean strainer head loss is 0.094 feet. Both values of pressure drop are at the maximum flow rate of 6800 gpm and 210°F, the saturation temperature for the minimum containment pressure.

Thus the maximum total strainer and debris bed head loss is 1.03 feet, which is within the NPSH margin for the limiting case of the ECCS pumps. The NPSH margin for all other cases and for all of the other ECCS pumps exceeds the limiting margin of 1.05 feet.

NPSH Margin for SBLOCA Cases (Audit Item):

GL 2004-02 Response Audit Report, Open Item 6 concerns evaluating NPSH margin for SBLOCA cases. DNC, however, has concluded that no formal evaluation is needed for NPSH margin for SBLOCA cases. The NPSH margin for the limiting case of a HPSI pump with a LBLOCA bounds the NPSH margin for any smaller break. This is shown in the LBLOCA case, where the HPSI pump is injecting with the reactor coolant system (RCS) at atmospheric pressure, which leads to the highest HPSI flows of any break. Any SBLOCA is assumed to maintain the RCS full. This significantly reduces the HPSI pump flow and, thus, reduces the required HPSI pump NPSH and hence, will increase the NPSH margin. Containment spray flows would likely not be affected. Some SBLOCAs will not raise containment pressure sufficiently to actuate containment spray. A break larger than a SBLOCA, which does not maintain the RCS full, would be similarly bounded by the NPSH margin for a LBLOCA. This is demonstrated because the HPSI flows will be lower (than for a LBLOCA) and the NPSH margin is higher. Debris loading for a smaller break may produce a thin-bed but would not create a head loss equal to the highest head losses tested on the strainer. This is a reasonable conclusion because the thin-bed head loss is dependent on the LBLOCA particulate load, which cannot occur with a SBLOCA.

Non-Conservatisms Affecting NPSH Available to ECCS Pumps (Audit Item):

GL 2004-02 Response Audit Report Open Item 7 relates to observations of potentially six minimum containment sump water level non-conservatisms, which were found in DNC analysis and that can affect minimum water level and the NPSH available to the ECCS pumps. The DNC response was to resolve the observation with revision to both the water holdup and minimum water level calculations, as discussed in the balance of this section.

i. A flat containment floor was assumed at elevation -22 feet 6 inches when audited. The floor is actually sloped with the highest elevation at -22 feet 6 inches and the lowest at -22 feet 9 inches.

   Response: The water holdup calculation was revised to account for the floor slope. The floor was conservatively assumed to slope linearly from -22'6" to -22'9". Accounting for obstructions, approximately 1265 ft^3 of water was found to be below elevation -22'6", which is now included in the holdup calculation.

ii. The ventilation ducts in the lower containment were assumed to remain intact during a LOCA and displace water, thus increasing the pool height.

   Response: The water holdup calculation was revised to conservatively assume that the ventilation ducts below the minimum water level would fill with 895 ft^3 of water.

iii. The GL 2004-02 Response Audit Report observed that the calculation had no provision for water droplets in transit from the containment spray header to the pool, or the water filling the normally empty containment spray pipes.

   Response: The water holdup calculation was revised to determine the volume of water in transit from the containment spray headers to the pool

(252 ft^3) and to determine the volume of water required to fill the containment spray pipes (214 ft^3).

iv. Water held up in condensate films on containment structures has not been adequately accounted for.

Response: The water holdup calculation was revised to include water held up on heat sink surfaces (493 ft^3).

v. The minimum water level calculation did not appear to address all SBLOCAs, such as a break near the top of the pressurizer, which could result in additional water holdup in the RCS above the vessel nozzles.

Response: Both the minimum water level and holdup calculations have been revised. The minimum water level calculation uses results from the holdup calculation that accounts for water held up from the containment floor. The minimum water level and holdup calculations both assume for all SBLOCAs that the RCS remains full. In the minimum water level calculation, the only water on the floor is from the Refueling Water Storage Tank (RWST). Thus, all SBLOCAs are addressed.

vi. The minimum water level calculation audited did not account for a limited volume of water holdup in the refueling cavity that could be due to a partial drain screen blockage.

Response: The water holdup calculation was revised to fully address the potential for refuel drain partial screen blockage. Blockage of the refuel drain screens is not considered credible because most debris will pass the large hole size of the screens. Additionally, debris has to navigate from the break in the RCS piping to enter the refuel pool and the path to the drain for any debris is convoluted, especially for large debris. Nevertheless, the holdup calculation conservatively determines holdup of approximately 300 ft^3 of water in the refueling pools.

The parameters described in the balance of this section also relate to the minimum water level and water holdup calculations that have been revised.

A minimum water level of 5.6 feet was determined for a LBLOCA and 4.5 feet for a SBLOCA. The LBLOCA water level is used in the determination of NPSH margin for the ECCS pumps. The use of the LBLOCA water level for the calculation of available ECCS pump NPSH remains conservative with the following inputs and justification:

- Any break which does not empty the safety injection tanks (SITs) would be considered a SBLOCA, which results in an RCS pressure at recirculation that limits HPSI pump flow. Consequently, the HPSI pump required NPSH for a SBLOCA is approximately 2 feet lower than when the HPSI pump is discharging into a depressurized (atmospheric) RCS, which is assumed to exist for a LBLOCA in NPSH calculations.

- The break that does not empty the SITs is a break where the RCS pressure does not reach 200 psig. The primary system pressure reaches and steadies at approximately the SIT injection pressure of 215 psia for the limiting SBLOCA of 0.08 ft^2. A break area of 0.08 ft^2 equates to approximately a 4-inch diameter circular break.

- Maximum recirculation flow from each HPSI pump, with the RCS at 200 psia, is approximately 635 gpm for the limiting case of maximum flow with a diesel failure. At 635 gpm, the required NPSH for any of the HPSI pumps is approximately 20 feet. Maximum HPSI flow with the RCS pressure at atmospheric is at least 685 gpm. Required NPSH for 685 gpm is 22 feet.

- The difference in required NPSH for the HPSI pumps is at least 2 feet between the case where the RCS is at 200 psia and the case where the RCS is at atmospheric pressure. This 2 feet difference in required NPSH exceeds the difference between the large and small break water levels (approximately 1.1 feet).

- Since a break size of 0.08 ft^2 triggers some SIT injection, a larger break size (not calculated) will result in complete emptying of the SITs and would thus ensure that the large break water level exists on the containment floor.

- Although the maximum break size that results in less than the large break water level collecting on the containment floor has not been explicitly calculated, it is reasonable to assume that the SITs empty and the large break water level exists on the containment floor by a break that is not much larger than the 0.08 ft^2 (4-inch diameter). It is also reasonable to assume that any break smaller than the 4-inch diameter results in an RCS pressure that ensures that HPSI pump flow is limited, such that the increase in NPSH margin created by lower required NPSH more than compensates for the potentially lower water level.

H. COATINGS EVALUATION:

Coatings ZOI for strainer design and testing (except for chemical effects testing and downstream wear analysis) was done using a coatings ZOI of 10D as recommended in the NRC SE to NEI 04-07. Coatings debris characteristics are similarly consistent with the approved methodology in NEI 04-07. The MPS2 GL 2004-02 Response Audit Report contains a detailed description and evaluation of coatings. The NRC reviewed coatings ZOI and coatings debris characteristics and found them acceptable with the exception of Open Items 8 and 9 from the audit that are discussed below. The conclusions reached in the audit remain correct.

Open Item 8 is the validation of the visual assessment methodology of determining qualified coatings.

Electric Power Research Institute (EPRI) Report TR-109937, "Guideline on Nuclear Safety-Related Coatings" states that, "Coatings degrade in manners that are easily detected visually and prior to detachment." The subsequent section in this guideline states, "The most effective means to conduct a thorough coatings condition assessment and detect coating degradation is through visual inspection."

Condition assessments (performed in the aggregate) are the result of comprehensive visual inspections of the coatings inside containment. There are no anomalous or significantly large failures of coatings inside the MPS2 containment building. Based upon observed conditions, coatings inside containment have performed as expected. There is no reason to believe that the existing coating systems will not continue to perform as designed including during a postulated LOCA event.

Specific reasons that visual inspections are considered to be the most suitable means for performing these assessments include:

- The tests are non-destructive
- Visual inspections are consistent with ALARA guidance
- Visual inspections provide a wider sample than local in-situ tests

Adhesion testing has been performed at four nuclear plants and reported in EPRI Report 1014883, “Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings,” August 2007. This testing showed that aged, visually intact, design basis accident (DBA)-qualified coatings (from various manufacturers) that exhibit no visual anomalies (i.e., no flaking, chipping, blistering) continue to exhibit system pull-off adhesion at or in excess of the originally specified minimum value of 200 psi. As a result, visual inspection is considered adequate for determining the condition of DBA qualified and acceptable coatings at MPS2.

Open Item 9 is the justification that zinc primer alone (which remains in some areas after removal of degraded top coat) remains a qualified coating system.

The MPS2 steel liner plate is coated with an inorganic zinc primer and modified epoxy topcoat material for corrosion protection. Due to degradation of the topcoat, portions of the topcoat have been removed leaving only the zinc primer. Following initial pressure testing of the containment building, narrow, linear blisters were found in some areas on the liner plate. This coating degradation was limited to blistering of the epoxy topcoat from the underlying inorganic zinc primer. Degradation of the topcoat has also occurred due to impact damage during refueling and maintenance activities.

The ability of a coating system or application to perform, as intended, is determined primarily through controlled qualification testing. For these tests, inorganic zinc primer material is applied onto steel coupons and subjected to aggressive environmental conditions. This includes temperatures, pressures, dose, and chemical exposures for the postulated DBA conditions.

The following reports summarize the DBA testing of coating materials and applications, which represent the MPS2 inorganic zinc primer on steel configuration.

- Carboline Company Report No. 01461 (Radiation and DBA testing of various Carboline coatings), 1976
- Carboline Company Report No. 01629 (Radiation and DBA testing of various Carboline coatings), 1978

Removal of loose topcoat epoxy material from the steel liner plate (inside the MPS2 containment) leaves an acceptable inorganic zinc prime coat for corrosion protection. This configuration has been satisfactorily tested to DBA conditions and found to be acceptable for continued service at MPS2.

Since the NRC GSI-191 audit, MPS2 has adopted a coatings ZOI of 5D. The strainer was designed and tested using a coatings ZOI of 10D as described in the GL 2004-02 Response Audit Report. Subsequently, the debris generation and debris transport calculations have been revised to use a coatings ZOI of 5D to determine the quantity of coatings debris for any future analysis and testing, (e.g., head loss testing for chemical effects and analysis of downstream wear). MPS2 surfaces with DBA qualified/acceptable coatings subject to a LOCA jet include carbon steel (structural steel and liner plate) and concrete walls. Additional margin is included in the qualified coating total to account for uninsulated pipe.

DBA-acceptable original coatings for MPS2 carbon steel surfaces are CarboZinc 11 primer with Phenoline 305 topcoat. These coatings were tested by the manufacturer under simulated operating and incident conditions and certified to fully comply with all the requirements of the American National Standards Institute (ANSI) Standard N-101.2 (1972) Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities.

WCAP-16568-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," June 2006, tested steel coupons coated with CarboZinc 11 with an intermediate coat and topcoat of Carboguard 890N. This combination simulates the original coating of structural steel and liner plate coatings used at MPS2. The WCAP documents that the Carboguard 890N topcoat is equivalent to the original Phenoline 305 that is no longer manufactured.

A portion of the structural steel and liner plate in containment has had the topcoat (Phenoline 305) removed due to damage or poor adherence of the topcoat. WCAP-16568-P tested steel coupons coated with one coat of CarboZinc 11 with no topcoat. This is considered to be equivalent to the untopcoated CarboZinc 11 in the MPS2 containment.

Concrete walls in the ZOI have an original coating of Keeler & Long No. 6548 (surfacer), Keeler & Long No. 7107 (primer), and Keeler & Long epoxy enamel (finish coat). These are DBA acceptable coatings and are similar to the coatings for concrete surfaces tested in WCAP-16568-P.

Replacement coatings at MPS2 for structural steel and liner plate inside containment are DBA-qualified epoxy coatings. These include Carboline 890 (now called Carboguard 890N), Ameron 400NT, and Keeler & Long 9600N or Keeler & Long 6548/7107 primer with an optional finish coat of Keeler & Long E-1 or D-1. Testing of steel coupons in the WCAP included testing with a prime coat and finish coats of Carboguard 890N and a prime coat of Keeler & Long 6548/7107 Epoxy with a finish coat of Keeler & Long D1 9140 Epoxy Hi-Build White Enamel. The coating on these coupons is considered to be equivalent to the replacement coatings allowed for use in MPS2 containment except for the Ameron 400NT maintenance system. Because the Ameron 400NT is a DBA-qualified coating, its performance is expected to be similar to the coating systems tested in the WCAP. This is based on the control and use of qualified coating systems through approved application procedures via the site coatings and linings program.

Replacement coatings systems allowed for steel and concrete or masonry surfaces in containment are DBA-qualified systems and are expected to perform similarly to the coating systems tested in the WCAP. Thus use of a 5D ZOI for these coatings is acceptable.

The specific coating systems tested by Westinghouse were all DBA-qualified/acceptable coating systems and the test conditions adequately simulated the MPS2 containment and RCS parameters. The test apparatus was set up to simulate an instantaneous pipe break with a 30 second blowdown time which is postulated to occur for the limiting double ended guillotine LOCA at a typical PWR.

The pressure of the fluid source in the test was 2200 psia and the normal operating pressure of the MPS2 RCS is 2250 psia. The temperature of the fluid source for the testing was 530°F, while the cold leg and hot leg nominal temperatures of MPS2 RCS are 550°F and 604°F, respectively. The conditions were chosen so as to be directly applicable to PWRs without any scaling. The differences in pressure and temperature between the test setup and the MPS2 RCS are not considered significant for the purposes of determining the amount of coating destroyed by a LOCA jet.

All DBA-qualified/acceptable coatings were required to undergo rigorously specified testing as detailed in the WCAP and the MPS2 FSAR. Per the WCAP, "DBA qualified/acceptable epoxy coatings will perform similarly, regardless of the manufacturer or the specific formulation. The basis for this similarity in performance is derived from the acceptance testing that coatings systems undergo to earn the label of 'DBA Qualified/Acceptable coating system....' " The WCAP adequately justifies that all DBA qualified/acceptable coatings are expected to perform similarly to those specific qualified coating systems tested.

All of the coatings tested for the WCAP testing program were newly applied coatings that were not irradiated prior to jet impact testing. Qualified coatings installed in the MPS2 containment are approximately 30 years old and have been exposed to normal containment conditions including temperature and radiation environment for normal operations. Maintenance of those coatings has consisted of periodic visual inspections and removal and replacement of damaged or detached qualified coatings. The coatings applied to structural steel and concrete or masonry walls at MPS2 were DBA acceptable when they were applied and they have been maintained consistent with industry standards. Coatings that have remained adherent and visually intact are considered qualified/acceptable for future use and are considered to meet all the requirements of qualified/acceptable coatings and are expected to perform no differently than the coatings tested in the WCAP under similar jet impact conditions.

Adhesion testing in EPRI Report 1014883, showed that aged, visually intact, DBA-qualified coatings (from various manufacturers) that exhibit no visual anomalies (i.e., no flaking, chipping, blistering) continue to exhibit system pull-off adhesion at or in excess of the originally specified minimum value of 200 psi. As a result, the WCAP testing with newly coated samples also applies to the existing DBA-qualified/acceptable coating in containment at MPS2.

It is reasonable to conclude that, based on the data presented above, the jet impingement data supports use of a 5D ZOI for all original and replacement qualified/acceptable coatings at MPS2. As described above, this data is applicable to MPS2 and, thus, the use of a 5D ZOI for qualified coatings is justified and acceptable.

Leaching of chlorides from coatings has been addressed under industry programs. Epoxy coatings are chemically inert in the post-LOCA containment sump pool and leaching of chlorides will not result in a significant quantity of reactant. Zinc coatings (primers) may release elemental zinc to the post-LOCA containment sump pool but industry testing has shown that there is very little zinc reaction with the post-accident sump fluid chemistry. Non-epoxy coatings consist of alkyds, urethanes, and acrylics. The amount of these coatings inside containment is generally limited to selected OEM (original equipment manufacturer) equipment, e.g., electrical junction boxes, and represents a small amount of the material in containment. These coatings do not represent a significant debris load in the sump. Furthermore, these coatings are, as a class, chemically benign and do not react in the post-LOCA sump fluid. They have been evaluated in industry programs to have a negligible impact on post-LOCA chemical precipitate production.

I. DEBRIS SOURCE TERM REFINEMENTS:

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions. The GSI-191 program is described in a procedure. The program establishes overall standards for containment conditions relative to containment recirculation sump performance.

Latent Debris:

Due to the large fibrous debris load in the MPS2 containment, latent debris is a relatively small contributor to strainer head loss. A thorough latent debris inventory was done and a conservative bounding number was chosen for the debris calculations. It is expected that further latent debris inventories will not be required and that latent debris will be adequately controlled through housekeeping and containment cleanup. As necessary, latent debris will be sampled and quantified using a calculation of containment surface area developed for this purpose. A thin-bed debris load is postulated to form on the containment sump strainer and has been shown in head loss testing to produce the worst-case debris bed head loss.

Changes to the plant housekeeping procedure and to the containment closeout procedure have been made to explicitly describe containment housekeeping expectations for worksites and the general containment area. Training has been provided to plant staff and supplemental staff to emphasize the need for and awareness of the importance of maintaining a clean containment.

Foreign Material Control:

The containment housekeeping procedure has been updated to prevent leaving material in containment that will impact the strainer debris load. This procedural direction includes direction to set up debris barriers at work areas, to cleanup work areas at the end of each shift, to remove barriers at the end of work, and to leave the work area cleaner than it was found at the start of the work.

The containment closeout procedure has been updated to require an inspection of containment for loose debris which could block the containment sump strainer. A sump inspection procedure has been updated to detail an inspection of the strainer for debris, damage, or blockage.

Permanent Plant Changes:

For permanent plant changes, the design review process has been updated to require that all design changes be reviewed using a series of detailed questions to determine if any potential debris source is to be put into containment. These questions are written to determine whether any debris source is being introduced, including fibrous or particulate material, coatings, stickers, particulate, aluminum, or calcium. If a debris source is introduced, the process requires that a detailed review be conducted to review the potential impact on ECCS sump strainer head loss.

Unqualified coating systems are not allowed to be applied to the inside of containment buildings. Small quantities of unqualified coatings on vendor supplied equipment may be allowed if added to the unqualified coating total maintained in a calculation by engineering. Coating systems used inside containment are required to comply with MPS2 containment coatings specification.

A coatings inspection and remediation procedure is also in place to ensure that the coatings inside containment remain within the requirements of the analysis.

Temporary plant design changes are subject to the design review process described above.

Insulation inside the MPS2 Containment is controlled by insulation specifications as well as by various plant drawings. Any deviations from these specifications are subject to the design review process described above.

Signs and labels are controlled by procedure and require Engineering approval for the use of labels inside containment that are of a type (plastics, adhesives) that would compromise GSI-191 assumptions.

Maintenance Activities:

The controls on debris sources described above prevent maintenance activities from introducing unevaluated debris sources into containment that will be left during plant operation.

Section 5.1 of the NRC SE describes five design and operational refinements related to debris source term. No additional refinements were taken at MPS2. The application of each of these refinements is summarized below.

Housekeeping and FME Programs:

Housekeeping and Foreign Material Exclusion (FME) programs are in place at MPS2 to maintain cleanliness of containment and to protect plant equipment by preventing entry of foreign material. Tags and stickers are controlled by procedure and the strainer is designed for bounding amounts of such items. A conservatively large surface area was added to the strainer to account for blockage by foreign material, including stickers, labels, and tags. Sufficient guidance exists to prevent addition of significant quantities of additional tags or stickers to containment.

Latent debris has been sampled twice in containment and may be sampled again if deemed necessary to ensure that the total amount of latent debris in containment remains below the amount used in the strainer design. This sampling is not necessary on a regular basis because the sampling that has been accomplished has demonstrated a significant margin to the acceptance criteria. Latent fiber is an insignificant fraction of the total fiber load and so can effectively be ignored. Latent particulate is only a small fraction (approximately 5% by volume) of the total particulate load used in the strainer design and so is likewise not expected to be a significant contributor to strainer head loss.

Debris Source Term Refinement:

The following debris source term refinements discussed by the NRC SE, but which were not applicable to MPS2 or were determined to not have a consequential increase in quality and safety in addressing GSI-191 at MPS2, were not performed.

- Existing Insulation Modification
- Other Equipment or Systems Modification
- Coatings Program Modification or Improvement

A debris source term refinement implemented at MPS2 includes a change-out of insulation:

- Change-out of insulation: Calcium silicate insulation was removed from the potential ZOI of a limiting LOCA so that no calcium silicate is in the debris bed or in the sump pool. Replacement of calcium silicate with NUKON™ fiber did not significantly alter the total NUKON™ fiber load and the head loss testing conducted for the strainer design assumed that the replacement of calcium silicate with NUKON™ fiber was complete. The insulation replacement was completed in the fall of 2006.

J. SCREEN MODIFICATION PACKAGE:

The original sump screen consisted of a vertical screen with 3/32" openings and approximately 110 ft^2 of surface area surrounding the existing ECCS pump suction lines. The replacement ECCS strainer is a finned strainer manufactured by AECL. It has a surface area of approximately 6120 ft^2 and is fully submerged on the start of recirculation. The strainer is composed of a solid housing which surrounds the ECCS suction pipes and from which protrude two solid rectangular headers. On each side of both of these headers are fins, the sides of which are perforated corrugated stainless steel. The maximum opening size in the fins is 1/16". Each of the fins is nominally 10 inches apart (center to center distance). Debris collects on and between the fins and filtered water passes into the fins and down the headers to the ECCS suction pipes. 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. Minimum strainer submergence for the replacement strainer is 6 inches by design. Actual submergence will be higher since a minimum water level of 4.23 feet was used for determining the strainer height and minimum submergence and minimum water level has been recalculated as described earlier in this response.

An active strainer design marketed by General Electric was considered for use at MPS2. Evaluations of the active strainer design concluded that the active design was not desirable primarily because an active design would introduce an active ECCS component into containment with an associated failure probability and inherent risk to generation. A properly designed passive strainer adequately ensures compliance with the long-term cooling requirements of 10 CFR 50.46(b)(5). No active backwashing design or other active design was considered.

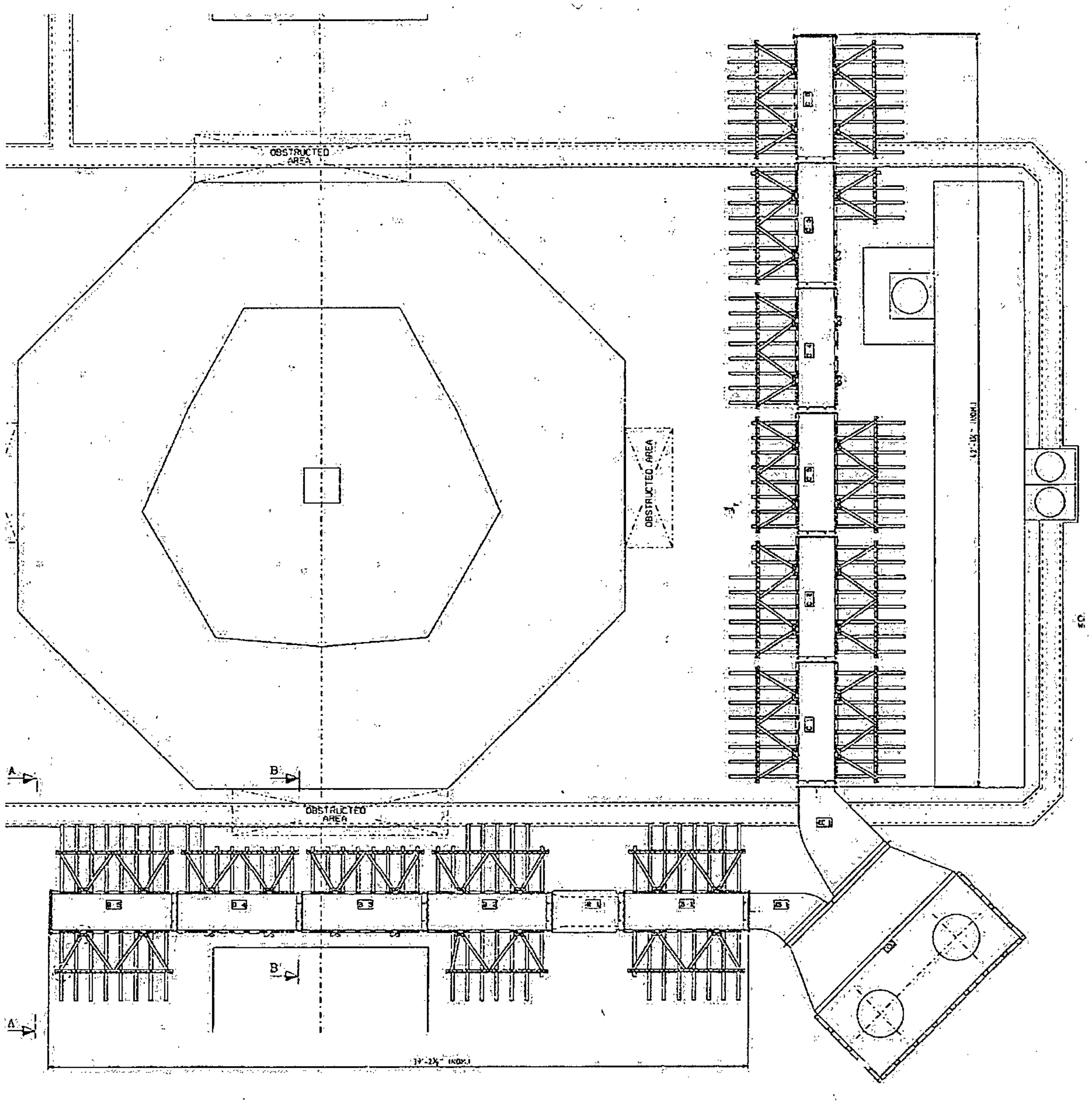
The MPS2 GL 2004-02 Response Audit Report contains a detailed description and evaluation of the screen modification package. The NRC reviewed the modification package along with multiple related documents and found them acceptable but found that not all were complete. The conclusions reached in the audit remain correct.

Open Item 10 from the audit concerns the completion of the planned revision to the design package. This revision to the design package will pull together all of the updated analyses and confirm that with the replacement strainer installed in the fall of 2006, MPS2 has reasonable assurance that long-term cooling will be maintained following a design-basis accident. Corrective actions implemented as a result of GL 2004-02 will all be complete upon completion and closeout of that design package. Completion of the design package will be done after resolution of both downstream effects and chemical effects, as discussed in the Dominion extension letter dated November 15, 2007 (Serial 07-0660).

K. SUMP STRUCTURAL ANALYSIS:

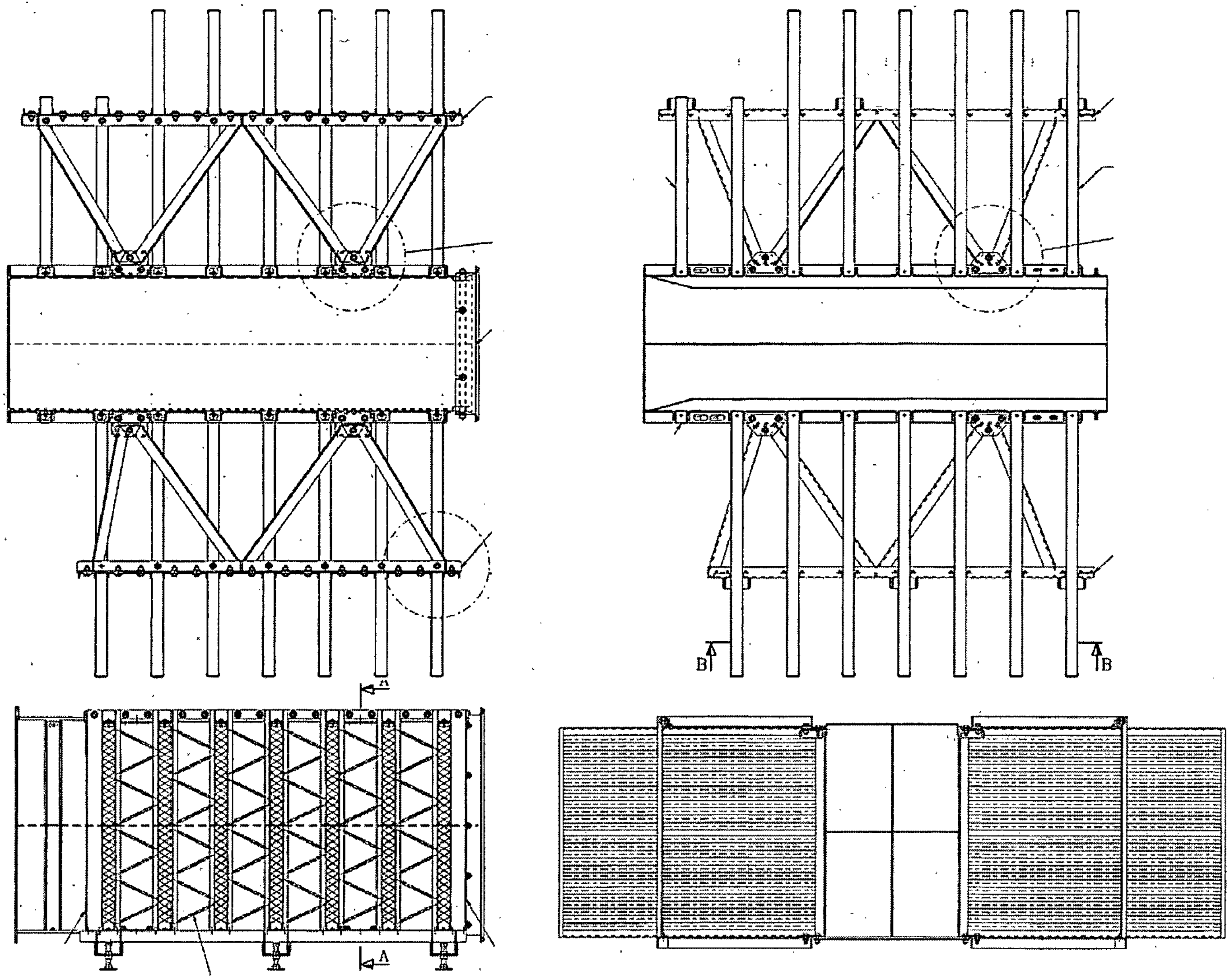
The sump strainer structure consists of a pump inlet closure surrounding the ECCS inlet lines, which are located near the containment exterior wall. From the pump enclosure two collection headers each extend approximately 40 feet in toward the center of containment. Each collection header contains 6 individual modules. Attached to each module are a varying number of perforated corrugated strainer fins, see Figure K-1.

Figure K-1: Strainer Structural Framing Layout:



The individual collection headers consist of a varying number of strainer fins bolted to the collection header to avoid existing interferences within the containment. The strainer fin sections consist of perforated corrugated stainless steel plate with solid plate edges. The collection header consists of stainless steel plate sections formed into a header section. The parts are connected with bolted and welded connections and bracing. (See Figures K-1 and K-2.)

Figure K-2: Strainer Header Sections:



The sump strainer is sufficiently removed from pipe whips, jets or missiles that they do not affect the design of the strainer. The design credits leak-before-break as allowed by the MPS2 Licensing Basis.

Inputs used in the structural design:

- Maximum differential strainer suction pressure = 15 psi
- Maximum sump water temperature = 250°F
- Maximum containment air temperature for strainer qualification = 300°F
- Maximum containment pressure = 54 psi

Structural analysis uses the methods of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NF Class 3 Component Supports as a guideline. The strainer is not a code component and it is replacing the sump screens, which were designed and installed to the AISC code. The strainer modules are analyzed using the ANSYS code utilizing a combination of shell and finite elements with linear elastic properties. Hydrodynamic loads from the response of a coupled water mass are included in the structural design. Required thermal growth is accommodated by the use of slotted connections with bushings and bolted connections.

Seismic analysis of the containment sump strainer is complete. The sump strainer structural analysis considers the following loadings, Dead Weight, Live Load, Operational Based Seismic Loading, Safe Shutdown Based Seismic Loading, Suction Pressure, Hydrodynamic Loading, and Thermal Loading. The governing load combination for the strainer design is the Dead Weight + Suction Pressure + Safe Shutdown Earthquake Inertia + Safe Shutdown Earthquake Hydrodynamic Loads. Seismic responses are developed and the governing two directional responses are combined utilizing the absolute sum (ABS) method in accordance with the unit FSAR requirements.

Tables K-1, K-2 and K-3 summarize analyzed stress and its comparison with allowed stress for various strainer components.

Table K-1: Typical Internal Module Plate Elements Stress Summary

Component	Maximum Stress (ksi)							
	Membrane		Membrane + Bending		Bearing		Shear	
	Stress	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*
Top Plate and top plate bent down	1.01	25.8	16.02	38.7	0.99	35.7	2.55	15.5
Bottom Plate	1.64		10.58		0.14		1.94	
Channel	10.56		12.45		-		3.05	
Horizontal Baffle Plate	4.05		4.05		-		0.66	
Vertical Baffle Plate	2.27		2.27		-		0.40	
Deflector Plate	2.23		2.27		-		0.50	
Adjustable End Flange	2.02		5.23		-		1.48	

Figure K-2: Typical Internal Module Beam Elements Stress Summary

Component	Maximum Stress (ksi)											
	Tension		Shear		Compression		Bending y-y		Bending z-z		Interaction	
	Stress	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*
Truss Web	1.33	21.4	0.01	14.3	-0.11	7.99	1.02	21.4	0.13	21.4	0.068	1
Truss Top plate	0.47		0.32		-0.28	5.78	0.03		6.13		0.336	
Truss Chord	0.95		0.37		-0.29	10.17	1.06		0.07		0.081	
Top Frame	0.69		0.54		-0.09	8.81	1.86		0.41		0.116	
Bottom Frame	0.40		0.55		-0.24	9.09	1.69		0.51		0.129	

Figure K-3: Typical Internal Module Bolts Stress Summary

Component	Maximum Stress (ksi)					
	Tension		Shear		Interaction	
	Stress	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*
Fins / Header	0.18	25.7	4.59	10.6	0.07	1
Header / Frames	0.71		3.12		0.03	
Truss / Frames	4.09		3.39		0.05	
Fins / Frames	0.90		2.61		0.02	
End Brace / Frames	0.02		0.38		0.01	

The strainer will be maintained in accordance with plant procedures. The procedures require verification that the sump strainer is ready for service and free of any detrimental damage that might have occurred during plant maintenance activities on a refueling basis interval, in accordance with Technical Specifications.

The MPS2 GL 2004-02 Response Audit Report contains an evaluation of sump structural analysis—pipe whip and jet impingement. The NRC reviewed the calculation PR-V and found it acceptable with the exception of Open Item 11 discussed below. The conclusions reached in the audit remain correct.

Open Item 11 concerns development of additional pipe whip and jet impingement detail in Calculation PR-V Revision 2 to account for the more extensive replacement strainer installed as corrective action for GL 2004-02 (as compared to the previous strainer). An evaluation of pipe whip and jet impingement has been completed for the replacement strainer. The evaluation provides the basis for discounting any new hazards interactions due to either pipe rupture effects or internally generated missiles and supports the acceptability of the replacement strainer installed during fall 2006 refueling outage at MPS2 under all MPS2 design basis hazards. The replacement strainer assembly has been determined to be beyond the potential range of any postulated pipe breaks within this region of the containment. All potential internally generated missile interactions have also been discounted as either being acceptable based on the design aspects of the strainer or being precluded due to the physical separation of the missile source from the sump screen by intervening structures.

Pipe whip and jet impingement concerns are not applicable to the reactor coolant piping because the MPS2 licensing basis includes approved leak-before-break analysis. Consistent with General Design Criteria 4 (GDC 4), the dynamic effects associated with pipe ruptures in the analyzed piping, including the effects of pipe whip and discharge of fluids have been excluded from the design basis.

L. UPSTREAM EFFECTS:

Flowpaths for water have been reviewed for all of the postulated breaks. The rooms containing the loop piping and all of the postulated breaks have grating for personnel access and are otherwise open to the containment floor. No significant amount of water can be kept from the containment sump pool by choke points. Much of the debris may be blown upward due to containment design and then washed down due to containment spray.

Much of the floor space in containment is grating which avoids the holdup of significant volumes of water on floors above the containment basement. No significant water can be stopped from flowing to the containment pool by debris blocking this grating due to the large surface area of grating in containment.

No debris racks are installed in the MPS2 containment. Curbs on floors with the potential for water holdup have been accounted for in the water holdup calculation.

The MPS2 GL 2004-02 Response Audit Report contains an evaluation of upstream effects. The NRC reviewed the upstream effects and found the MPS2 analysis acceptable with the exception of Open Items 12 and 13 that are discussed below. The conclusions reached in the audit remain correct.

Audit Open Item 12 concerns the non-conservatisms in the evaluation of water holdup. As described in the NPSH Section G above for the resolution of audit

Open Item 7, the water holdup calculation and minimum water level calculations have been revised to account for all of the identified non-conservatisms in the water holdup calculation and determination of minimum water level.

Audit Open Item 13 concerns the evaluation of the potential for refueling cavity holdup volume. As discussed above, the water holdup calculation has been revised to account for holdup in the refueling pools and to detail the potential for blockage of the refuel pool drain line screens. Clogging of the drains is not a concern during a LOCA. This was determined to be a reasonable conclusion, in part because the locations of the breaks are remote from the refueling cavities. It is not likely for large pieces of insulation debris to fall into the reactor cavity due to a break in one of the coolant loops. Both refueling cavities are clean and free of debris during plant operation. Administrative controls are in place to ensure that there is no loose debris in the containment including the refueling cavities. The 4-inch drain holes are covered with 18" x 18" x 18" box screens to prevent clogging from any debris falling into the cavity following an accident. Therefore, it is assumed that all the water that collects in the cavities is drained to the containment sump at –22.5 feet elevation.

Water holdup is calculated for the floor of the North and South refueling cavities. This calculation assumes that the drain line is unplugged and flow into the drain pipe can be conservatively treated as a broad-crested weir that produces a height of water in the refueling cavity of 0.3 feet in the North cavity and 0.347 feet in the South cavity. Thus, holdup of 119 ft^3 in the North refueling cavity and holdup of 180 ft^3 of water in the South refueling cavity is included in this calculation. No additional holdup in these refueling cavities need be assumed as detailed below.

Insulation (primarily NUKON™) will be dislodged from the reactor coolant piping and from the steam generator by the limiting break in the coolant piping. The debris generation calculation postulates that the radius of the spherical ZOI for NUKON™ insulation is 17D or 17 times the pipe diameter. For the limiting break of the 42-inch diameter hot leg, the ZOI is 17*42 = 714 inches or 59.5 feet. The elevation of the coolant piping is nominally 5.8 feet. The top of the ZOI would reach an elevation of 5.8 + 59.5 = 65 feet. The top of the steam generator is approximately elevation 63 feet and, thus, the ZOI encompasses the entire steam generator. The shape of the steam generator with its large protruding steam drum (and enclosing walls) would prevent significant insulation removal from the top of the steam generator due to a tortuous path for the steam and water jet issuing from the break and the significant loss of energy of the break jet. It is difficult to predict the energy dissipation of this jet, but in general, due to the multiple obstructions and bulbous steam drum, there is only a minimal direct path from the hot or cold leg to the top of the steam generator. Energy dissipation from the break jet will be significant prior to the break jet reaching the top of the steam generator. For the purposes of debris generation, this energy dissipation was conservatively ignored. However, for the purpose of determining the potential for clogging the refuel drain lines, this energy dissipation can be reasonably postulated to prevent large pieces of insulation from being dislodged from the upper part of the steam generator and landing in either the north or the south refueling pool.

Each of the two refueling pools has an 18" x 18" x 18" strainer installed over the drain line to prevent drain line clogging. The strainers have a 2" x 2" stainless steel wire cloth over a stainless steel box frame. The 2" x 2" wire cloth provides four equal squares per square inch, which gives a ½-inch square hole. The base of the enclosure is ½-inch thick stainless steel plate in 2 triangular pieces. This arrangement provides a ½-inch gap at the bottom of the enclosure to allow water to drain to the floor level.

There is no significant potential for large pieces of insulation debris to reach the refueling pool floors. However, small pieces and individual strands of insulation fiber have the potential to reach the refueling pool since the energy of the break is designed to be directed upwards in containment. These small pieces and individual fibers are widely dispersed and not able to block the ½-inch openings either at the base of the drain line strainer enclosure or in the wire cloth due to the relatively high water velocities in the refueling pool and the relatively large size of the openings.

M. DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS:

The flow paths downstream of the containment sump were analyzed to determine the potential for blockage due to debris passing through the sump strainer. The strainer opening size is 1/16". The acceptance criteria were based on WCAP-16406-P Rev. 0.

The strainer design ensures that gaps at mating surfaces within the strainer assembly and between the strainer and the supporting surface are not in excess of the strainer hole size of 1/16-inch.

The component blockage evaluations were done for all components in the recirculation flow paths including, but not limited to, throttle valves, flow orifices, spray nozzles, pumps, heat exchangers, and valves. The methodology employed in this evaluation is based upon input obtained from a review of the recirculation flow path shown on piping and instrument diagram drawings and plant procedures. The steps used in obtaining the flow clearance are as follows:

- Determine the maximum characteristic dimension of the debris (clearance through the sump strainer).
- Identify the recirculation flow paths.
- Identify the components in the recirculation flow paths.

- Review the vendor documents (drawings and/or manuals) for the components to obtain flow clearance dimensions.

- Determine the blockage potential using a comparison of flow clearance through the component and flow clearance through the sump strainer.

- Identify the components that require a detailed evaluation and investigation of the effects of debris on their capability to function.

The MPS2 GL 2004-02 Response Audit Report contains an evaluation of downstream effects. The NRC reviewed the downstream effects and found the analysis of component debris blockage acceptable. The MPS2 evaluation of component wear was incomplete as described in Open Items 14 through 25. The conclusions reached in the audit remain correct.

The downstream wear calculation evaluates component wear using the guidance in WCAP 16406-P Draft Rev. 1. The evaluation addressed:

- Wear in the HPSI pumps, LPSI pumps, CS pumps, manually throttled valves, motor operated valves, orifices, and heat exchangers. The evaluation of the wear effects on the performance of these components is also evaluated.

- Evaluation of the downstream instrumentation, including temperature indicators, pressure indicators, and flow indicators for potential blockage due to the presence of debris.

Pumps:

The abrasive and erosive wear of a pump's internal subcomponents resulting from pumping debris-laden water will cause an increase in the flow clearances of the pump. The increase in flow clearances is evaluated for impact on hydraulic performance of the pump. A second issue associated with wear is the changing system resistance curve due to wear of components, like valves and orifices. The results indicate that all valves, plate orifices, multi-stage orifices, and containment spray nozzles pass the criteria and, therefore, the effect on system flow rates is negligible.

Hydraulic performance and mechanical dynamic performance of each ECCS pump is found acceptable because the total abrasive and erosive wear of small clearance areas on the ECCS pumps is less than the wear allowance for replacement, and are therefore acceptable. Thus, the hydraulic performance of the ECCS pumps will not be impaired due to abrasive and erosive wears of pump subcomponents while pumping debris-laden water for 30 days post-LOCA.

Wear on the mechanical seal on each of the ECCS pumps has been estimated as approximately 0.026 inches. This wear has been evaluated to be acceptable because for a normal functioning mechanical seal, the potential increase of the tight gap between the primary and the mating ring is continuously being closed by the spring force and, thus, tight clearance is maintained. The sealing faces are also highly polished and run with a very thin film of cooling liquid, which prevents even minute debris particles larger than the film thickness from entering the gap and causing wear.

Heat Exchangers:

The tube wall thickness of the heat exchangers minus the tube wall thickness lost to erosion is greater than the minimum tube wall thickness required to withstand the internal tube design pressure. Therefore, the heat exchanger tubes have sufficient tube wall thickness to withstand the erosive effect of the debris-laden water for a period of 30 days post-LOCA.

Other components:

All manually throttled valves, plate orifices, multi-stage orifices, and containment spray nozzles in the recirculation flow path pass the criteria set forth per WCAP-16406 Draft Rev. 1 and, therefore, the calculated wear will have insignificant effect on the system flow. No further evaluation is required. No piston check valves are required to close during recirculation so no further evaluation is required.

Instrumentation:

Instrumentation that is mounted either on the top or side of the piping is not susceptible to failure due to plugging. The velocity of the fluid as well as the orientation of the instrument in the pipe will allow the debris to continue flowing beyond the instrumentation. Flow transmitters whose orientation could not be determined were evaluated separately. The flow velocity past these transmitters was found to be sufficiently high to prevent debris from settling into and plugging the instrument. Therefore, the identified instrumentation will not be adversely affected by debris in the recirculation flow path.

No hardware changes were found to be necessary. The evaluation of downstream wear per WCAP-16406 Rev. 1 (final) is in progress. The changes required to the wear evaluation as a result of Rev. 1 to WCAP-16406 will be completed, consistent with NRC approval of the extension to the schedule for corrective actions of GL 2004-02, described in DNC letter dated November 15, 2007. Audit Open Items 14 through 25 will be addressed as a part of a summary report on downstream wear when the evaluation is complete. Hardware (design) changes as a result of the evaluation of wear (based on WCAP-16406 Rev. 1) will be identified upon completion of the evaluation.

N. DOWNSTREAM EFFECTS - FUEL AND VESSEL:

The MPS2 GL 2004-02 Response Audit Report contains no evaluation of downstream effects for the fuel and vessel. The MPS2 evaluation of downstream effects for the fuel and vessel was incomplete as described in Open Item 26.

Since the audit, WCAP-16793 Rev. 0 has been published concerning the impact of fibrous, particulate, and chemical precipitate debris on the fuel and long-term cooling. The WCAP results provide reasonable assurance that long-term core cooling will be established and maintained post-LOCA considering the presence of debris in the RCS and core. The debris composition includes both particulate and fiber debris, as well as post-accident chemical products.

The results of WCAP-16793 are applicable to MPS2. The WCAP evaluated three topical areas. They are:

- Evaluation of fuel clad temperature response to blockage at the core inlet
- Evaluation of fuel clad temperature response to local blockages or chemical precipitate on fuel clad surface
- Evaluation of chemical effects in the core region, including potential for plate-out on fuel cladding

General Conclusions of Assurance of Long-Term Core Cooling and Their Basis:

The WCAP states that the evaluation of these three areas discussed above, in conjunction with other information, provides reasonable assurance of long-term core cooling with debris and chemical products in recirculating fluid for all plants. The basis for these general conclusions is provided in items i through v below, in the balance of this section. DNC concluded this basis to be applicable to MPS2 from the plant specific information that is discussed in more detail by the next section concerning applicability of WCAP-16793-NP.

i. Blockage at the Core Inlet and Adequate Flow:

Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Test data has demonstrated that any debris that bypasses the strainer is not likely to build up an impenetrable blockage at the core inlet. While any debris that collects at the core inlet will provide some resistance to flow, in the extreme case that a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue.

ii. Decay Heat Removal with Debris Collection at Fuel Grids:

Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the strainer is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does not occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue.

iii. Fibrous Material on Fuel Cladding Surfaces:

Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling.

iv. Prediction of Chemical Deposition from Chemical Effects on Fuel Cladding:

Using an extension of the chemical effects method developed in WCAP-16530-NP to predict chemical deposition of fuel cladding, two sample calculations using large debris loadings of fiberglass and calcium silicate, respectively, were performed. The case demonstrated that decay heat would be removed and acceptable fuel clad temperatures would be maintained.

v. Mixing Volumes and Adequate Boric Acid Dilution:

As blockage of the core will not occur, the mixing volumes assumed for the current licensing basis boric acid dilution evaluations are not affected by debris and chemical products transported into the RCS and core by recirculating coolant from the containment sump. Therefore, the current accepted licensing calculations that demonstrate appropriate boric acid dilution to preclude boric acid precipitation remain valid.

Site-Specific Applicability Review of WCAP-16793-NP General Conclusions:

DNC concluded the applicability of the WCAP-16793-NP to MPS2 by performance of a review of plant specific information that is discussed in more detail by the balance of this section. This effort demonstrates all of the WCAP evaluations and conclusions are directly applicable to MPS2. It provides a reasonable assurance that for MPS2 the long-term core cooling will be established and maintained post-LOCA, even when considering the presence of debris in the RCS and core. A detailed plant specific review of the following five effects is included.

- Blockage at the Core Inlet
- Collection of Debris on Fuel Grids
- Collection of Fibrous Material on Fuel Cladding
- Chemical Deposition on the Fuel Cladding
- Boric Acid Precipitation

i. Blockage at the Core Inlet:

The AECL strainer design installed at MPS2 has holes with a diameter of 1/16" inch (0.0625 inches). This is bounded by the assumption made in Section 2.1 of WCAP-16793-NP that the replacement strainers will have a hole diameter on the order of 0.1 inches.

Reduced scale testing conducted at AECL for MPS2 included bypass testing, which determined the maximum amount of fiber bypass that would occur for the MPS2 replacement strainer. Fiber bypass testing was conducted with the maximum fiber load and no added particulate. The amount of fiber that passed through the strainer was so low that for accurate determination of concentration and size, a scanning electron microscope (SEM) evaluation was required. SEM analysis of the fiber bypass test results showed that 90% of the fibers that bypassed the strainer were less than 1.2 mm long and the maximum length of fiber that bypassed the strainer was 2 mm. The strainer hole size is 1/16" or 1.6 mm. Based on bypass test results, 99.7% of the fiber was calculated to be filtered on the first pass through the strainer. This equates to less than 0.2 ft^3 of fiber passing through the strainer. This is entirely consistent with the observations of bypass testing discussed in Section 2.1 of WCAP-16793-NP.

A bounding WCOBRA/TRAC analysis of blockage at the core inlet is contained in the WCAP. Parameters selected for this analysis bound the US PWR fleet by modeling a limiting break type which consists of a double-ended cold leg break which limits flow at the core inlet combined with the faster debris build-up that occurs for a high flow hot leg break. Also modeled was the limiting vessel design, which was determined to be the Westinghouse downflow plant. As stated in Section B.1.3 of Appendix B of WCAP-16793-NP, downflow plants are the most limiting design. This is because the only means for limited flow to enter the core is through the lower core plate. Converted upflow plants are less limiting since bypass flow in the barrel/baffle region can enter near the top of the core. CE designed plants like MPS2 are similar to a converted upflow plant since limited flow may enter near the top of the core, and, therefore, the design is non-limiting with respect to core inlet flow. Thus, the WCOBRA/TRAC analysis presented in WCAP-16793-NP bounds MPS2.

The WCOBRA/TRAC analysis demonstrates that sufficient liquid can enter the core to remove core decay heat once the plant has switched to sump recirculation with up to 99.4 percent blockage at the core inlet.

ii. Collection of Debris on Fuel Grids:

As discussed above, the MPS2 specific bypass testing is entirely consistent with the WCAP conclusion that it is unlikely that the combination of fibrous and particulate debris will collect in numerous grid locations to restrict flow sufficiently such that long-term core cooling is challenged.

The WCAP contains ANSYS and first-principle calculations that demonstrate that the fuel rod will continue to be cooled even with significant blockages around the fuel grids. These analyses demonstrated that even with a completely blocked grid strap, core decay heat was adequately removed. As stated in Section C.4 of Appendix C to WCAP-16793-NP, the parameters for these calculations were derived from the WCOBRA/TRAC analysis, the results of which bound post-LOCA long-term core cooling clad temperatures for the entire US PWR fleet. Thus, these calculations bound MPS2 and the conclusion that numerical and first principle analyses have demonstrated that core decay heat removal will continue applies to MPS2.

iii. Collection of Fibrous Material on Fuel Cladding:

The WCAP refers to generic information for NEA.CNSI/R (95)11 "Knowledge Base for Emergency Core Cooling System Recirculation Reliability," February 1996, to support the conclusion that fibrous debris will not tightly adhere to the surface of fuel cladding should it enter the core region. The report reflects testing applicable to both NUKON™ and Knauf ET Panels. This is representative of the fibrous debris expected at MPS2 and, thus, the conclusions of the WCAP are applicable to MPS2.

iv. Chemical Deposition on the Fuel Cladding: *(in progress)*

The WCAP documents an Excel spreadsheet called LOCADM that will calculate the deposition of chemical precipitates and the resultant maximum clad temperature. MPS2 specific input parameters were entered into the LOCADM spreadsheet. Preparation of an MPS2-specific calculation is in progress; however, draft calculation results show that the maximum clad temperature should be well below the acceptance criterion of 800°F. The preliminary results are essentially the same as shown in Figure 5-3 of WCAP-16793-NP. Completion of this calculation is expected by the end of the first quarter of 2008. Thus, the conclusion of the WCAP that most plants using this methodology will be able to demonstrate acceptable long-term-core cooling in the presence of core deposits is applicable to MPS2.

The WCAP also presents a discussion of the potential for protective coatings debris to melt or otherwise adhere to the fuel clad surfaces. The coatings evaluated in the WCAP include zinc rich primers which are used on steel surfaces at MPS2, epoxies which are used on steel and concrete surfaces at MPS2, and unqualified coatings such as alkyds, urethanes, and acrylics of which MPS2 has a limited amount. The WCAP concludes that the zinc that could come into the sump pool solution from the zinc primer presents neither a chemical precipitate concern (consistent with industry testing results such as the ICET tests and the Westinghouse WCAP-16530 results) nor a heat transfer inhibition concern since the thermal conductivity of zinc is relatively high. The WCAP further concludes that the amount of non-epoxy coatings (unqualified coatings) is limited and, in the case of alkyds is not expected to have a deleterious impact. For epoxy coatings, the WCAP shows that the temperatures of the sump pool will, in the limiting cases, remain below the 350°F temperature at which epoxy coatings tend to begin to degrade. Additionally, the WCAP states that epoxy coating does not adhere to fuel clad surfaces. Below 350°F, epoxy coatings will not degrade. Additionally, epoxy coatings are chemically inert and are not expected to leach significant amounts of compounds that could contribute to the formation of chemical precipitates.

v. Boric Acid Precipitation:

As discussed above, the evaluation of the potential for blockage for MPS2 is entirely consistent with the evaluations documented in the WCAP. Since blockage will not occur for MPS2, the WCAP conclusion that the current accepted licensing calculations that demonstrate appropriate boric acid dilution to preclude boric acid precipitation remain valid is applicable to MPS2.

O. CHEMICAL EFFECTS:

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

The resolution of chemical effects at MPS2 has three main components. They are:

- An assessment of potential precipitates includes determination of reactive material amounts present in the containment sump pool, pH and temperature profiles in containment, and a review of existing test and scientific literature data. This determines which precipitates are likely to form in the post-LOCA sump pool. This assessment is complete.
- Benchtop testing to determine potential precipitates. *(In progress)*

- Reduced scale testing to determine head loss due to potential precipitates. *(In progress, as required)*

Overall Chemical Effects Strategy:

Westinghouse has published WCAP-16530, Rev. 0, which the NRC staff has accepted as a conservative methodology to evaluate head loss due to post-accident chemical precipitates. DNC has contracted with AECL to perform an assessment of potential chemical precipitates in the sump pool that may contribute to head loss. This assessment by AECL uses plant specific data on reactive materials, sump water volume, and post-LOCA debris constituents, bench top and precipitation test results from the WCAP-16530, ICET test results, results from NRC sponsored research on chemical effects, and a thorough literature survey to determine the precipitates likely to form in the MPS2 containment sump pool post-LOCA.

The AECL assessment will be followed by appropriate bench top tests to verify the formation or lack of formation of expected precipitates. If necessary, reduced scale testing will be done to determine the impact of precipitate formation on debris bed head loss. It is expected that the precipitates formed would be added to the reduced scale test tank after a debris bed had formed to conservatively determine the long-term head loss in the tank.

The AECL assessment has concluded the following from the review of available data.

- Aluminum corrosion can give rise to the formation of an aluminum bearing precipitate, but aluminum corrosion is inhibited by phosphates and silicates and the precipitate formed includes boron, which can affect the mass or flocculation properties of any aluminum bearing precipitate formed.

- Only low concentrations of iron, nickel, magnesium, and zinc dissolved into the simulated sump water and these species did not lead to the formation of significant amounts of precipitates.

- With trisodium phosphate (TSP) present, precipitates containing calcium, phosphate, and carbonate can form.

- Concrete does not appear to be a significant source of calcium.

- Precipitate formation is dependent on kinetic as well as thermodynamic properties.

- There is no evidence of direct chemical effects from paint debris. Radiolysis of organic compounds leaching from the coatings will lead to formation of carbonate species that could nominally lower the sump pH.

- WCAP-16530 suggests that sodium aluminum silicate is a possible precipitate. However, a review of the literature of thermodynamics and kinetics of aluminosilicate formation suggests its formation is unlikely under PWR post-LOCA sump water conditions.

If sodium aluminum silicate precipitate fails to form, the two precipitates of concern at MPS2 are aluminum hydroxide or oxyhydroxide and calcium phosphate.

Aluminum Hydroxide Precipitation:

As part of the assessment of chemical effects, AECL developed an aluminum release equation from the available aluminum corrosion data. The calculated aluminum release into the MPS2 sump water (including both unsubmerged and submerged aluminum) is expected to result in an aluminum concentration of approximately 4.4 mg/liter (ppm). This total for dissolved aluminum concentration does not exceed the solubility of amorphous aluminum hydroxide. Thus, aluminum hydroxide precipitates are not expected to form in the MPS2 containment sump pool.

Calcium Phosphate Precipitation:

Calcium phosphate is highly insoluble. Significant quantities of phosphate will be present in the MPS2 containment sump pool due to the dissolution of the TSP buffer. ICET test 3 included calcium silicate and TSP. A white precipitate (calcium phosphate) was observed to form early in the test and subsequent head loss testing at Argonne led to the issuance of IN 2005-26 to alert licensees to the adverse head loss impacts of calcium phosphate.

Calcium Silicate insulation that was installed on piping and the Regenerative Heat Exchanger within the break ZOI has been removed and replaced with fibrous (NUKON™) insulation. Other calcium silicate insulation exists in containment; however, it is outside the break ZOI and is jacketed with stainless steel. Thus, it makes no contribution to the debris load. As a result of the removal of calcium silicate insulation from the ZOI, there is no calcium silicate insulation postulated to be in the debris in the containment pool or on the strainer following a LOCA.

In ICET 2 (30 days) containing TSP and NUKON™, no precipitate was observed to form and in tests conducted as part of WCAP-16530 (24 hour tests), no precipitate was observed to form in mixtures containing NUKON™ and TSP. In the absence of added calcium silicate, the amounts of calcium released from fiberglass are likely insufficient to result in the precipitation of calcium phosphate.

For MPS2, the bench top testing will determine whether calcium is released from the other sources of insulation in containment including mineral fiber and mineral wool, both of which are known to contain calcium. Uncertainty exists as to whether sufficient calcium will be released from concrete and insulation materials postulated to be present in the MPS2 containment sump pool to form a measurable amount of calcium phosphate precipitate. Bench top dissolution and precipitation testing will be done to determine how much calcium is released into the sump pool.

Dominion could modify the TSP buffer used to control the containment pool pH at MPS2 following a LOCA if that change becomes necessary to eliminate formation of calcium phosphate precipitate.

Reactive Materials in Containment:

Table O-1 shows the amounts (i.e., surface area) of potentially reactive materials that are:

- Submerged in the containment pool following a LOCA, and
- In the containment spray zone following a LOCA.

In addition to Table O-1, boric acid, LiOH (RCS), and TSP are postulated to be part of the containment sump pool since the RCS and RWST are borated, RCS contains LiOH, and TSP is present in baskets on the floor of containment to buffer the sump pool water.

Sources of debris postulated to be dislodged by the LOCA jets and to be deposited in the containment sump pool include NUKON™ fibrous insulation, mineral wool, mineral fiber, coatings, latent debris, and stainless steel RMI insulation.

Other materials in the containment that may be present in the containment sump pool include items such as copper (primarily in air piping) that has been shown to not be reactive in the post-LOCA environment, and leachates from coatings that are not postulated to form in significant quantities in the post-LOCA environment to produce precipitates. Other containment materials have been evaluated as having only an insignificant potential for becoming a part of the containment sump pool. Insignificant contributors include leaking oil (e.g., from pumps, hydraulic cranes) that will tend to float on the surface of the water and not react to form precipitates, corrosion inhibitor in the closed cooling water systems that are not postulated to experience pipe breaks as a result of a LOCA, and air dryer desiccant that is not postulated to be released to the containment sump pool.

No metallic paint is in containment except zinc-rich primer used on steel surfaces described below. All insulation in containment is jacketed with stainless steel except some NUKON™ insulation blankets that are covered with a heavy-duty fiberglass cloth covering by the manufacturer. These NUKON™ insulation blankets are not submerged in the post-LOCA containment sump pool.

Table O-1: Surface Areas of Materials Subjected to Containment Spray and Submergence

Material	Surface Area Submerged (ft^2)	Surface Area Exposed to Containment Spray (ft^2) (does not include submerged material)
Aluminum	24	1876
Zinc (from galvanized steel)	15,000	130,000
Zinc (from non-top coated inorganic zinc primer)	10,000	205,500
Zinc (from top coated inorganic zinc primer)	0	0
Carbon Steel (uncoated)	500	0
Concrete (uncoated)	3700	2600
Fibrous Insulation (NUKON™)	1400 ft^3	0
Mineral Fiber Insulation	297 ft^3	0
Mineral Wool Insulation	159 ft^3	0

The total of inorganic zinc primer in the table above includes all of the steel surfaces that have the inorganic zinc primer. The original coating system for these surfaces put an epoxy topcoat on the zinc primer. Some of this epoxy topcoat has been removed. Based on visual observation, a maximum of approximately 10% of these surfaces no longer have the epoxy top coat.

A total of 4695 ft^2 of galvanized scaffolding is stored in containment. This scaffolding is all submerged. The scaffolding surface area is included in the table above as part of the galvanized zinc material.

There is no uncoated concrete by design within the containment structure. The values above are established to allow margin for discovery of uncoated concrete and to account for concrete stripped of coating by the LOCA break jets.

The minimum sump pool water volume at MPS2 is 41,800 ft^3 (volume is at 212°F). This is the water volume corresponding to a SBLOCA that takes into account water losses due to holdup. Table O-2 shows the ratios of material to test tank water volume used in the ICET tests and the corresponding ratios of material to containment sump minimum water volume found in the containment. ICET test 2 most closely resembles the MPS2 containment sump pool. ICET test 2 was a test of TSP buffered water with NUKON™ insulation and no calcium silicate.

Table O-2: Comparison of Material Ratios Between ICET and MPS2 Containment

Material	ICET Test Ratio	MPS2 Ratio	Comparison Factor (ICET Ratio / MPS2 Ratio)	% of material submerged		% of material un-submerged	
				ICET	MPS2	ICET	MPS2
Zinc in Galvanized Steel	8.0 (ft^2/ft^3)	3.5 (ft^2/ft^3)	2.3	5	12	95	88
Inorganic Zinc Primer Coating (non-top coated)	4.6 (ft^2/ft^3)	5.2 (ft^2/ft^3)	0.9	4	5	96	95
Inorganic Zinc Primer Coating (top coated)	0.0 (ft^2/ft^3)	0 (ft^2/ft^3)	N/A	-	-	-	-
Aluminum	3.5 (ft^2/ft^3)	0.05 (ft^2/ft^3)	70	5	1	95	99
Carbon Steel	0.15 (ft^2/ft^3)	0.012 (ft^2/ft^3)	12.5	34	100	66	0
Concrete (surface)	0.045 (ft^2/ft^3)	0.15 (ft^2/ft^3)	0.3	34	60	66	40
Insulation Material (fiberglass)	0.137 ft^3/ft^3	0.044 ft^3/ft^3	3.1	75	100	25	0

Based on Table O-2, the MPS2 material ratios are below the ICET test ratios for all material except non-top coated zinc primer and concrete surface area.

As previously discussed, all of the zinc primer in containment is assumed for this table to be non-top coated. This is very conservative as only about 10% of the top coat on the zinc primer is actually removed. Additionally, zinc does not produce significant amounts of precipitate in the post-LOCA sump pool as demonstrated in WCAP-16530.

Uncoated concrete surface area is postulated to be significantly larger in the MPS2 containment than in the ICET tests. However, as discussed above, no concrete surface area is uncoated by design and the values in Table O-2 above represent conservative bounding values for uncoated concrete. No concrete particulate was calculated for the MPS2 containment. The break jet is postulated to remove qualified coating from concrete surfaces. As demonstrated in the Westinghouse Chemical Effects testing documented in WCAP-16530, concrete is not a significant contributor to the formation of particulate precipitate. Any concrete particulate that may form as a result of the LOCA jet is heavier than water, sinks to the bottom of the containment sump pool, and is thus not included in the debris load. Additionally, concrete is a potential source of calcium. Formation of large amounts of calcium phosphate precipitate, however, does not appear to have occurred in ICET 2 despite the presence of the uncoated concrete and concrete particulate.

Containment Pool pH:

MPS2 uses TSP to neutralize the sump water in containment post-LOCA. The TSP is stored in baskets mounted on the floor of the bottom level of containment and dissolves as the coolant collects on the containment floor. The minimum amount of TSP required on the floor of containment is calculated to ensure that the long term pH of the containment sump water is at least a pH of 7.0.

The best estimate maximum pH values as a function of time post-accident are summarized in the table below. The pH in the first minute is dependent on RCS water mixed with Safety Injection tank water. The pH gradually drops as RWST is injected prior to the start of recirculation. Once mixing of the sump pool is complete (conservatively assumed to occur at the start of recirculation for maximum pH), the pH rises to as high as 8.3 and then drifts down over the following 30 days as TSP is dispersed throughout the water in the containment (including holdup water).

Table O-3: Maximum Containment Sump Pool pH:

Time	Maximum pH (at 77°F)
0-1 minute (prior to RWST injection)	6.7
1 min – 27.5 min (start of recirculation)	5.9
27.5 minutes (recirculation mixing complete)	8.3
30 days (long term value)	8.0

The long-term minimum value of sump pool pH is 7.1. This pH could occur at the beginning of the fuel cycle and would be maintained throughout the recirculation mission time once the TSP is all dissolved and the sump pool is well mixed. At the end of the fuel cycle, the minimum pH is somewhat more than 7.1. This occurs because the boron concentration in the RCS would be near zero ppm and the minimum pH is calculated assuming maximum boron concentrations in the water volumes, which are injected into containment post-LOCA.

The long-term minimum pH value of 7.1 is based upon the following assumptions:

- Primary components would drain their maximum volume of water to the containment sump during a large break LOCA
- Maximum boric acid concentration in the Boric Acid Storage Tanks (BASTs)
- Maximum boric acid concentration in the RCS
- HCl is formed by degradation of electrical cable insulation in the post-accident environment
- HNO3 is formed by irradiation of the containment atmosphere and sump water

The long-term maximum value of sump pool pH is approximately 8.3. This pH could occur at the end of the fuel cycle and would be maintained throughout the recirculation mission time once the TSP is all dissolved and the sump pool is well mixed. At the beginning of the fuel cycle, the maximum pH is somewhat less since the boron concentration in the RCS would be at its maximum.

The long-term maximum pH value assumes:

- Minimum boron concentration in RWST, SIT and BAST
- No boron in RCS

- All TSP dissolved
- No production of HCl or HNO_3

Transient Containment Pool pH Values:

During pool fill up at the beginning of the accident, the sump pool water could experience short-term pH values above and below the long-term values previously described. The higher pH values would exist in the vicinity of the TSP baskets before sump pool mixing and the lower values would exist in much of the containment pool away from the TSP baskets before recirculation begins. These transient values are only expected to exist during pool fill up. Once the mixing of TSP with sump water and pool fill up completes (within 1 hour for any break which is expected to produce significant debris), pH of the sump water remains between the minimum and maximum long-term pH values described above.

The transient minimum value of sump pool pH is bounded by a pH of 4.6. This transient value would occur during pool fill up in most of the areas away from the TSP baskets before mixing occurred in the sump pool. The bounding value of 4.6 assumes an RCS boron concentration somewhat higher than what is found in the RCS at the beginning of the fuel cycle.

This pH value of 4.6 is based upon the following assumptions:

- A maximum boron concentration of RCS and Boric Acid Storage Tanks (BAST)
- A minimum RCS water volume and maximum BAST water volume
- No interaction with TSP
- No production of HCl or HNO_3 (a reasonable expectation due to the short time interval before TSP dissolves)

The transient maximum value of sump pool pH is difficult to quantify and will only exist in the immediate vicinity of the TSP baskets prior to sump recirculation and mixing of the sump pool water. This transient value would only occur for a short period during pool fill up when the sump water level is approximately 2 feet (less than half of its ultimate value) and if all of the TSP is postulated to slump and dissolve in the rising water. This is the highest value of pH that could occur and assumes an RCS boron concentration of zero consistent with the end of the fuel cycle.

This transient maximum pH value assumes:

- The TSP slumps and then dissolves with only 2 feet of water on the floor (approximately half the minimum water level)
- A minimum sump boron concentration in RWST, SIT, and BAST

- No boron in RCS
- No production of HCl or HNO_3

At the end of the fuel cycle, the minimum pH is somewhat higher than 4.6 because there is minimal boron left in the RCS.

ICET Test Comparison:

MPS2 uses TSP as a buffering agent and has no calcium silicate in the debris load. Thus, ICET 2 is considered to be most similar to MPS2 conditions following a LOCA.

Table O-4: Comparison of ICET 2 Conditions with Post LOCA Conditions in MPS2 Containment

Parameter	MPS2	ICET 2
Boron Concentration	2482 ppm	2800 ppm
TSP Concentration	0.0153 gmol/liter	0.0102 gmol/liter
pH	Initial sump pool pH could be as low as 4.6 prior to TSP dissolution. Long-term minimum pH is 7.1. Long-term maximum pH is 8.3.	Initial pH was 4.3 prior to addition of TSP or any debris. Average pH recorded during first week of test (after the first four hours) was 7.2 and average for final three weeks of test was 7.3.

For ICET 2, the concentration of TSP was found using 3786 g TSP added and 949 liters of test tank water based on information in the test report for ICET 2. Molecular weight of TSP is 390.1 g/g-mole.

For MPS2, the concentration of TSP was found using 15,211 lb_m TSP and the volume of water for the SBLOCA used above (41,800 ft^3). This volume of water is corrected to the ICET test tank temperature of 140°F using the ratio of specific volumes for pure water resulting in a volume of 40,735 ft^3.

The lower boron concentration in containment leads to a somewhat higher pH than was seen in the ICET environment.

The TSP concentration in the ICET Test 2 is the same order of magnitude as is expected in the MPS2 containment. Since the TSP concentration is higher in the MPS2 containment, a somewhat higher pH likely results in the MPS2 containment than was seen in the ICET test tank.

Differences exist between the ICET 2 and the MPS2 containment environment temperature. For ICET 2, the temperature was held at a constant 140°F. At MPS2 sump water temperature does not remain constant but instead peaks relatively early in the accident and decreases over time.

The expected MPS2 containment water and air temperature profiles are given in the Table O-5.

Table O-5: Maximum Containment Air and Water Temperature

Time (seconds)	Containment Air Temperature (°F)	Time (seconds)	Sump Pool Water Temperature (°F)
0	120	0	120
1	208	0.1	131
9	281	1	188
12	281	5	236
14	282	8	243
23	282	12	244
48	282	30	246
50	282	60	248
55	282	120	254
150	284	180	258
153	284	200	259
180	284	400	266
300	281	462	266
1030	268	580	265
1480	261	780	262
2060	253	980	258
4260	234	1180	253
7060	221	1380	248
10120	212	1580	244
15320	204	1780	240
20120	200	3160	216
80120	173	3470	212
92320	183	4570	208
99920	186	6070	203
111800	188	7370	198
164300	185	8770	194

Time (seconds)	Containment Air Temperature (°F)	Time (seconds)	Sump Pool Water Temperature (°F)
200300	183	9970	191
403800	175	26240	189
454300	172	325100	177
1000800	152	500100	175
2592300	138	750100	169
-	-	1000100	162
-	-	1500100	153
-	-	2000100	147
-	-	2592100	142

The peak temperature expected in containment sump water is higher than the constant temperature of the water in the test tank, but the gradual temperature reduction brings the water temperature, after several days, to roughly equivalent to the ICET tank water temperature.

Existing Margins for Chemical Effects:

MPS2 replacement strainer surface area is approximately 6120 ft^2 compared to the actual tested area of 5620 ft^2, leaving a margin of 500 ft^2 of strainer surface area. Approximately 150 ft^2 of this surface area is for foreign material, leaving a margin of approximately 350 ft^2.

MPS2 strainer was sized using a ZOI for coatings of 10D. The WCAP-16568-P justified a ZOI for coatings of 5D for qualified non-top coated inorganic zinc primer, and a ZOI for coatings of 3D for qualified epoxy coatings. The results of WCAP-16568-P have been determined to be applicable to MPS2. The use of a 5D ZOI for qualified coatings lowers the particulate debris load by approximately 16 ft^3, which is a reduction of approximately 50%. This reduction in particulate debris potentially lowers the maximum thin-bed head loss and thus provides margin for chemical precipitates.

No settling of particulate debris is credited in the analytical debris transport calculation and settling was minimized as much as possible during head loss testing by stirring of the test tank water. Much of the particulate debris is epoxy coating with a density of approximately 94 lb/ft^3 that will promote settling.

Bench Top Testing:

The purpose of the bench top testing involves the following goals:

- Demonstrate that the solubility behaviors of aluminum hydroxides and calcium phosphates obtained from the literature are reproducible and conservative under the conditions expected at MPS2.
- Confirm that precipitates with the required properties (settling rate, particle size and filterability, as specified in WCAP-16530) can be produced, prior to producing these materials on a scale large enough for head loss testing. In addition, tests will be carried out to determine the optimum storage time for the precipitates.
- Determine if the water chemistry that will exist during the chemical effects testing will have any effect on the properties of the walnut shells used in the tests as a surrogate for paint particulate.
- Determine if materials in the containment of MPS2 release an amount of calcium that is insufficient to produce a significant mass of calcium phosphate precipitate.

The bench top tests will consist of dissolution testing and precipitation testing.

Dissolution tests will determine the amount of calcium released from representative materials. Representative quantities of concrete (as coupons), fiberglass, mineral wool, and mineral fiber will be placed in a flask with a solution of borated water at the appropriate pH. Samples of the water will be periodically measured for constituents such as calcium, silicon, aluminum, and properties such as pH, and conductivity. At the completion of the dissolution tests, a sample of the solution will be cooled and filtered. A representative amount of TSP will be added to the test vessel and the solution will be visually examined for precipitation, measured for turbidity, and filtered to determine precipitate formation.

Precipitation testing for aluminum hydroxide will be carried out under the following conditions:

- Conditions representative of those expected at the highest aluminum concentrations reached.
- Conditions representative of those expected when the pH and temperature change rapidly, as these rapid changes may induce precipitation.

<u>Open Items From the Audit Report Related to Chemical Effects</u>:

Chemical effects for MPS2 were not evaluated during the January 2007 Audit of GL 2004-02 corrective actions. The evaluation of chemical effects was at that time incomplete, as described in the GL 2004-02 Response Audit Report by Open Items 27, 28, and 29 (See Table P-2).

Open Item 27 is the general open item for resolution of chemical effects at MPS2. Its partial resolution is described below.

Open Item 28 concerns the potential for coatings to contribute to chemical effects by leaching chemical constituents that could form precipitates or affect other materials (e.g., increase aluminum corrosion rates). This open item has a response to the NRC by the PWR Owners Group for the industry, (ADAMS Accession No. ML070950119), which has been accepted on issuance of the draft Safety Evaluation for WCAP-16530 (ADAMS Accession No. ML073190618). Thus, Open Item 28 is considered closed.

Open Item 29 relates to the potential for some of the coating chips to turn into a product that causes high head loss. Resolution of this item is addressed in WCAP-16793, discussed in Section N, which shows that zinc primer (used at MPS2) will not cause formation of significant amounts of precipitate. Non-epoxy coatings (alkyds, urethanes, and acrylics) are present in only relatively small amounts and are not expected to create chemical precipitates, and epoxy coatings are chemically inert and retain their structural integrity at temperatures up to 350°F, which exceeds the containment sump pool temperature. The vast majority of coatings in the containment are DBA-qualified or acceptable and have been subjected to DBA testing, which includes prolonged exposure to post-LOCA conditions. DBA-qualified and DBA acceptable coatings will not turn into a product that causes high head loss under post-LOCA conditions.

Unqualified coatings in the containment are tracked and are present in relatively small amounts (approximately 9 ft^3). High humidity and temperature conditions exist post-LOCA and unqualified coatings are conservatively assumed to fail. Their failure is conservatively assumed to result in 10 micrometer particulate that fully transports to the strainer. In reality, much of the volume of these coatings will not fail as shown in EPRI Report 1011753 “Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings.” Unqualified coatings that do fail will fail relatively slowly, will fail as a variety of particle sizes, will tend to settle, and will transport to the strainer over a significant time interval thus limiting their impact on head loss.

Considering all these conservatisms, there is reasonable assurance that coatings will not turn into a product which causes high head loss, and if some of the unqualified coatings do turn into such a product, the amount will be very limited and not likely to have a significant impact on strainer head loss.

P. LICENSING BASIS:

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

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

Changes to the Final Safety Analysis Report (FSAR) will be made consistent with the description of the modifications and analyses described in this letter. No other changes to plant licensing bases were identified.

4. RESPONSE INDEX FOR REQUESTED INFORMATION:

DNC received NRC letter dated February 9, 2006, requesting additional information (RAI) on the MPS2 response to GL 2004-02. An Audit Report was also received, issued in NRC letter dated August 30, 2007, on the results of the January 2007 NRC audit of associated corrective actions. Responses to both the questions in the RAI and open items from the GL 2004-02 Response Audit Report are referenced by this section. Table 4-1 lists the RAI questions and Table 4-2 shows the Audit Report open items. Both tables provide a cross-reference to the section/content of this attachment or the Audit Report itself that provides relevant information/answer(s).

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
1. Identify the name and bounding quantity of each insulation material generated by a large-break loss-of-coolant accident (LBLOCA). Include the amount of these materials transported to the containment pool. State any assumptions used to provide this response.	Section 3.2 of NRC Audit Report of MPS2 Response Letter Section B and Section H
2. Identify the amounts (i.e., surface area) of the following materials that are: (a) Submerged in the containment pool following a loss-of-coolant accident (LOCA), (b) In the containment spray zone following a LOCA, (i) Aluminum (ii) Zinc (from galvanized steel and from inorganic zinc coatings) (iii) Copper (iv) Carbon steel not coated (v) Uncoated concrete Compare the amounts of these materials in the submerged and spray zones at your plant relative to the scaled amounts of these materials used in the Nuclear Regulatory Commission (NRC) nuclear industry jointly-sponsored Integrated Chemical Effects Tests (ICET) (e.g., 5x the amount of uncoated carbon steel assumed for the ICETs).	Section O: Chemical Effects
3. Identify the amount (surface area) and material (e.g., aluminum) for any scaffolding stored in containment. Indicate the amount, if any, which would be submerged in the containment pool following a LOCA. Clarify if scaffolding material was included in the response to Question 2.	Section O: Chemical Effects
4. Provide the type and amount of any metallic paints or non-stainless steel insulation jacketing (not included in the response to Question 2) that would be either submerged or subjected to containment spray.	Section O: Chemical Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
5. Provide the expected containment pool pH during the emergency core cooling system (ECCS) recirculation mission time following a LOCA at the beginning of the fuel cycle and at the end of the fuel cycle. Identify any key assumptions.	Section O: Chemical Effects
6. For the ICET environment that is the most similar to your plant conditions, compare the expected containment pool conditions to the ICET conditions for the following items: boron concentration, buffering agent concentration, and pH. Identify any other significant differences between the ICET environment and the expected plant-specific environment.	Section O: Chemical Effects
7. (Not Applicable)	
8. Discuss your overall strategy to evaluate potential chemical effects including demonstrating that, with chemical effects considered, there is sufficient net positive suction head (NPSH) margin available during the ECCS mission time. Provide an estimated date with milestones for the completion of all chemical effects evaluations.	Section O: Chemical Effects
9. Identify, if applicable, any plans to remove certain materials from the containment building and/or to make a change from the existing chemicals that buffer containment pool pH following a LOCA.	Section O: Chemical Effects
10. If bench top testing is being used to inform plant specific head loss testing, indicate how the bench top test parameters (e.g., buffering agent concentrations, pH, materials, etc.) compare to your plant conditions. Describe your plans for addressing uncertainties related to head loss from chemical effects including, but not limited to, use of chemical surrogates, scaling of sample size and test durations. Discuss how it will be determined that allowances made for chemical effects are conservative.	Section O: Chemical Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
11. Provide a detailed description of any testing that has been or will be performed as part of a plant-specific chemical effects assessment. Identify the vendor, if applicable, that will be performing the testing. Identify the environment (e.g., borated water at pH 9, de-ionized water, tap water) and test temperature for any plant-specific head loss or transport tests. Discuss how any differences between these test environments and your plant containment pool conditions could affect the behavior of chemical surrogates. Discuss the criteria that will be used to demonstrate that chemical surrogates produced for testing (e.g., head loss, flume) behave in a similar manner physically and chemically as in the ICET environment and plant containment pool environment.	Section O: Chemical Effects
12. For your plant-specific environment, provide the maximum projected head loss resulting from chemical effects (a) within the first day following a LOCA, and (b) during the entire ECCS recirculation mission time. If the response to this question will be based on testing that is either planned or in progress, provide an estimated date for providing this information to the NRC.	Section O: Chemical Effects
13. Not Applicable	-
14. Given the results from the ICET 3 tests (ADAMS Accession No. ML053040533) and NRC-sponsored head loss tests (Information Notice 2005-26 and Supplement 1), estimate the concentration of dissolved calcium that would exist in your containment pool from all containment sources (e.g., concrete and materials such as calcium silicate, Marinite^{TM}, mineral wool, kaylo) following a LBLOCA and discuss any ramifications related to the evaluation of chemical effects and downstream effects.	Section O: Chemical Effects
15. Not Applicable	-

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
16. Not Applicable	-
17. Not Applicable	-
18. Not Applicable	-
19. Not Applicable	-
20. Not Applicable	-
21. Not Applicable	-
22. Not Applicable	-
23. Not Applicable	-
24. Not Applicable	-
25. Describe how your coatings assessment was used to identify degraded qualified/acceptable coatings and determine the amount of debris that will result from these coatings. This should include how the assessment technique(s) demonstrates that qualified/acceptable coatings remain in compliance with plant licensing requirements for design basis accident (DBA) performance. If current examination techniques cannot demonstrate the coatings' ability to meet plant licensing requirements for DBA performance, licensees should describe an augmented testing and inspection program that provides assurance that the qualified/acceptable coatings continue to meet DBA performance requirements. Alternately, assume all containment coatings fail and describe the potential for this debris to transport to the sump.	Section H: Coatings Evaluation
26. Not Applicable	-
27. Not Applicable	-
28. Not Applicable	-

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
29. Your GL response indicates that you may pursue a reduction in the radius of the ZOI for coatings. Identify the radius of the coatings ZOI that will be used for your final analysis. In addition, provide the test methodology and data used to support your proposed ZOI. Provide justification regarding how the test conditions simulate or correlate to actual plant conditions and will ensure representative or conservative treatment in the amounts of coatings debris generated by the interaction of coatings and a two-phase jet. Identify all instances where the testing or specimens used deviate from actual plant conditions (i.e., irradiation of actual coatings vice samples, aging differences, etc.). Provide justification regarding how the deviations are accounted for with the test demonstrating the proposed ZOI.	Section H: Coatings Evaluation
30. The NRC staff's safety evaluation (SE) on the NEI guidance report, NEI 04-07, addresses two distinct scenarios for formation of a fiber bed on the sump screen surface. For a thin bed case, the SE states that all coatings debris should be treated as particulate and assumes 100% transport to the sump screen. For the case in which no thin bed is formed, the staff's SE states that the coatings debris should be sized based on plant-specific analyses for debris generated from within the ZOI and from outside the ZOI, or that a default chip size equivalent to the area of the sump screen openings should be used (Section 3.4.3.6). Describe how your coatings debris characteristics are modeled to account for your plant-specific fiber bed (i.e., thin bed or no thin bed). If your analysis considers both a thin bed and a non-thin bed case, discuss the coatings debris characteristics assumed for each case. If your analysis deviates from the coatings debris characteristics described in the staff-approved methodology, provide justification to support your assumptions.	Section H: Coatings Evaluation Audit Report, Section 3.7

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
31. Your submittal indicated that you had taken samples for latent debris in your containment, but did not provide any details regarding the number, type, and location of samples. Please provide these details.	Audit Report, Sections 3.3 and 3.4 Section D: Latent Debris
32. Your submittal did not provide details regarding the characterization of latent debris found in your containment as outlined in the NRC SE. Please provide these details.	Audit Report, Sections 3.3 and 3.4 Section D: Latent Debris
33. Was/will "leak-before-break" be used to analyze the potential jet impingement loads on the new ECCS sump screen?	Section A: Break Selection
34. You indicated that you would be evaluating downstream effects in accordance with WCAP-16406-P. The NRC is currently involved in discussions with the Westinghouse Owner's Group (WOG) to address questions/concerns regarding this WCAP on a generic basis, and some of these discussions may resolve issues related to your particular station. The following issues have the potential for generic resolution; however, if a generic resolution cannot be obtained, plant-specific resolution will be required. As such, formal RAIs will not be issued on these topics at this time, but may be needed in the future. It is expected that your final evaluation response will specifically address those portions of the WCAP used, their applicability, and exceptions taken to the WCAP. For your information, topics under ongoing discussion include: a. Wear rates of pump-wetted materials and the effect of wear on component operation b. Settling of debris in low flow areas downstream of the strainer or credit for filtering leading to a change in fluid composition c. Volume of debris injected into the reactor vessel and core region	No response required. Calculations in progress use the new Revision 1 to WCAP-16406, which is currently under NRC review.

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
d. Debris types and properties e. Contribution of in-vessel velocity profile to the formation of a debris bed or clog f. Fluid and metal component temperature impact g. Gravitational and temperature gradients h. Debris and boron precipitation effects I. ECCS injection paths j. Core bypass design features k. Radiation and chemical considerations l. Debris adhesion to solid surfaces m. Thermodynamic properties of coolant	
35. Your response to GL 2004-02 question (d)(viii) indicated that an active strainer design will not be used, but does not mention any consideration of any other active approaches (i.e., backflushing). Was an active approach considered as a potential strategy or backup for addressing any issues?	Section J: Screen Modification Package
36. You stated that selected insulation will be replaced, and that this replacement will reduce the postulated post-accident debris loading effects on the sump strainer. Please discuss the insulation material being removed and the material that will replace the selected insulation, including debris generation and characteristics parameters of the replacement insulation. Has the new insulation been evaluated in the debris generation, transport, head loss analyses and other sump design analyses?	Section B: Debris Generation/ ZOI (excluding coatings) Section C: Debris Characteristics Section O: Chemical Effects
37. You stated that for materials for which no ZOI values were provided in the Nuclear Energy Institute (NEI) guidance report "Pressurized Water Reactor Sump Performance Evaluation Methodology," NEI 04-07, or the associated staff SE, conservative ZOI values are applied. Please provide a listing of the materials for which this ZOI approach was applied and the technical reasoning for concluding the value applied is conservative.	Audit Report, Section 3.2 Section B: Debris Generation/ ZOI (excluding coatings)

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
38. You did not provide information on the details of the debris characteristics assumed in their evaluations other than to state the NEI and SE methodologies were applied. Please provide a description of the debris characteristics assumed in these evaluations and include a discussion of the technical justification for deviations from the SE-approved methodology.	Audit Report, Section 3.2 Section B: Debris Generation/ ZOI (excluding coatings) Section C: Debris Characteristics
39. Has debris settling upstream of the sump strainer (i.e., the near-field effect) been credited or will it be credited in testing used to support the sizing or analytical design basis of the proposed replacement strainers? In the case that settling was credited for either of these purposes, estimate the fraction of debris that settled and describe the analyses that were performed to correlate the scaled flow conditions and any surrogate debris in the test flume with the actual flow conditions and debris types in the plant's containment pool.	Section F: Head Loss and Vortexing
40. Are there any 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? In this case, dependent upon the containment pool height and strainer and sump geometries, the presence of the vent line or penetration could prevent a water seal over the entire strainer surface from ever forming; or else this seal could be lost once the head loss across the debris bed exceeds a certain criterion, such as the submergence depth of the vent line or penetration. According to Appendix A to Regulatory Guide 1.82, Revision 3, without a water seal across the entire strainer surface, the strainer should not be considered to be "fully submerged." Therefore, if applicable, explain what sump strainer failure criteria are being applied for the "vented sump" scenario described above.	Section J: Screen Modification Package
41. What is the basis for concluding that the refueling cavity drain(s) would not become blocked with	Section L: Upstream Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
debris? What are the potential types and characteristics of debris that could reach these drains? In particular, could large pieces of debris be blown into the upper containment by pipe breaks occurring in the lower containment, and subsequently drop into the cavity? In the case that large pieces of debris could reach the cavity, are trash racks or interceptors present to prevent drain blockage? In the case that partial/total blockage of the drains might occur, do water holdup calculations used in the computation of NPSH margin account for the lost or held-up water resulting from debris blockage?	
42. What is the minimum strainer submergence during the postulated LOCA? At the time that the re-circulation starts, most of the strainer surface is expected to be clean, and the strainer surface close to the pump suction line may experience higher fluid flow than the rest of the strainer. Has any analysis been done to evaluate the possibility of vortex formation close to the pump suction line and possible air ingestion into the ECCS pumps? In addition, has any analysis or test been performed to evaluate the possible accumulation of buoyant debris on top of the strainer, which may cause the formation of an air flow path directly through the strainer surface and reduce the effectiveness of the strainer?	Audit Report, Section 3.6.1 Section F: Head Loss and Vortexing
43. The September 2005 GL response stated that the licensee performed computational fluid dynamics analysis (CFD) of which outputs included global (entire containment) and local (near sump pit) velocity contours, turbulent kinetic energy contours, path lines and flow distributions for various scenarios. Please explain how you used these outputs to determine the amount of debris that transports to the sump screen.	Audit Report, Section 3.6 Section E: Debris Transport

Table 4-2: Information Response Index for NRC Audit Report Open Items:

Audit Report Open Items		Response
1.	The licensee had not confirmed that the "loop-seal pipe" piping arrangement does not result in a new limiting case for Break Criterion Case 3.	Section A: Break Selection Audit Report, Section 3.1
2.	The licensee had not finalized the Millstone Unit 2 debris generation calculations.	Section B: Debris Generation / ZOI (Excluding Coatings) Audit Report, Section 3.2
3.	The licensee had not evaluated the potential adverse effects of break flow drainage turbulence.	Section E: Debris Transport Audit Report, Section 3.5.4.5
4.	The licensee had not evaluated and resolved the potential for reduced pump NPSH margins and other adverse effects on the sump performance analysis as the result of a single failure of a LPSI pump to trip following the receipt of an SRAS.	Section F: Head Loss and Votexing Audit Report, Sections 3.6.2.2 and 3.6.1.6
5.	The licensee's had not resolved a 1.5 feet error in the HPSI pumps NPSH margin calculation.	Section G: Net Positive Suction Head (NPSH) Audit Report, Section 3.6.2.3.1
6.	The licensee had not completed the NPSH margin calculations for the SBLOCA cases.	Section G: Net Positive Suction Head (NPSH) Audit Report, Section 3.6.2.3.1
7.	The licensee should evaluate the impact of six potential minimum water level non-conservatisms identified by the staff and assess their impact on the minimum containment water level calculation. (This item appears in a draft audit report, issued July 13, 2007 and on page 63 of the final audit report.)	Section G: Net Positive Suction Head Audit Report, Section 3.6.2.3.3

Table 4-2: Information Response Index for NRC Audit Report Open Items:

Audit Report Open Items		Response
8.	The licensee had not validated its visual assessment methodology of determining qualified coatings.	Section H: Coatings Evaluation Audit Report, Section 3.7.2
9.	The licensee had not justified that residual zinc primer alone remains a qualified coating system after the topcoat is removed.	Section H: Coatings Evaluation Audit Report, Section 3.7.2
10.	The licensee had not completed the Millstone Unit 2 sump blockage modification package, it's included 10 CFR 50.59 evaluation, and supporting information and calculations.	Section K: Screen Modification Package Audit Report, Section 4.0, Pg. 73
11.	The Licensee had not completed development of additional pipe whip and jet impingement detail in Calculation PR-V, Revision 2 to account for the larger dimensions of the new sump strainers.	Section K: Sump Structural Analysis Audit Report, Section 5.1
12.	The licensee's evaluation of the potential water holdup flow mechanisms that result in the minimum volume in the sump pool did not appear to contain allowances for all locations and mechanisms for water holdup in the Millstone Unit 2 containment (e.g., empty containment spray piping filled during recirculation, water which may become tapped in containment ventilation ductwork, the airborne containment spray water volume during recirculation, the volume related to the sloping containment floor, and water sheeting on the surfaces of objects in containment such as equipment , cables, steel supports, ductwork, and containment walls).	Section L: Upstream Effects Audit Report, Section 5.2
13.	The licensee had not evaluated the potential for debris to be transported into the refueling cavity from LOCA blowdown and Containment Spray washdown, and subsequently result in a refueling cavity holdup volume.	Section L: Upstream Effects Audit Report, Section 5.2

Table 4-2: Information Response Index for NRC Audit Report Open Items:

Audit Report Open Items	Response
14. The licensee may need to re-assess ECCS operation during small-break LOCAs, medium-break LOCAs, and large-break LOCAs following component wear and pluggage evaluations.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
15. The licensee had not performed system flow and balance calculations to incorporate the results of downstream evaluations.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
16. The licensee determination of the characterization and properties of ECCS post-LOCA fluids (abrasiveness, solids content, and debris characterization) was not complete.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
17. System debris depletion quantification calculations were being revised and may also need to be re-assessed if the rates in the planned small-scale testing are greater than currently being used in draft documents.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
18. The licensee had not completed re-performing the Millstone Unit 2 Downstream Evaluation Report with regard to pump performance and operation.	Section M: Downstream Effects – Components and Systems
19. An evaluation of pump hydraulic degradation, total developed head (TDH), and flow due to internal wear had not been performed.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3

Table 4-2: Information Response Index for NRC Audit Report Open Items:

Audit Report Open Items		Response
20.	The range of pressures and flows used by the licensee to evaluate pump internal wear rates may not be adequate to predict degradation or assess operability in that minimum flows (per EOP) and/or pump run-out flows were not considered.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
21.	The draft downstream evaluation utilized a three-body, non-impeller pump erosive wear model. The internal wear mechanism for internal, non-impeller wear is two-body (NUREG/CP-0152 Vol. 5, TIA 2003-04, "Proceedings of the Eighth NRC/ASMR Symposium on Valve and Pump Testing," July 2004). A justification was not provided for the use of the three-body model.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
22.	The draft downstream evaluation utilized the criterion contained in American Petroleum Institute Standard (API) 610 as acceptance criteria for pump vibration. API 610 applies to 'new' pumps. The licensee did not provide an evaluation supporting the conclusion that the existing pumps are "as good as new."	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
23.	The licensee did not quantify additional pump seal leakage into the Safeguards Room due to wear or abrasion. The licensee has detailed alarm, alarm response and room environmental analyses. These analyses may need to be re-assessed after seal leakage is quantified.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
24.	The licensee had not assessed whether the system, piping, component flow resistance or flow balances have changed due to wear or clogging.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3

Table 4-2: Information Response Index for NRC Audit Report Open Items:

Audit Report Open Items	Response
25. The licensee had not assessed whether ECCS and CSS piping vibration response would change due to wear, clogging, changes in system resistance or changes in system operation.	Section M: Downstream Effects – Components and Systems Audit Report, Section 5.3
26. The licensee had not completed a complete revision of its analysis of downstream effects on the fuel and vessel.	Section N: Downstream Effects – Fuel and Vessel Audit Report, Section 5.3.2
27. The licensee had not resolved chemical effects.	Section O: Chemical Effects, Open Items… Audit Report, Section 5.4
28. The licensee had not resolved the potential for coatings to leach chemical constituents that could form precipitates or affect other materials (e.g., increase aluminum corrosion rates).	Section O: Chemical Effects, Open Items… Audit Report, Section 5.4
29. The licensee had not resolved potential changes to the paint itself due to the pool environment (i.e., the potential for some of the coatings chips to turn into a product that causes high head loss).	Section O: Chemical Effects, Open Items… Audit Report, Section 5.4

ATTACHMENT 2

GENERIC LETTER 2004-02 SUPPLEMENTAL INFORMATION FOR MILLSTONE POWER STATION UNIT 3

DOMINION NUCLEAR CONNECTICUT, INC. (DNC)
MILLSTONE POWER STATION UNIT 3

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

(Contents)

GENERIC LETTER 2004-02 SUPPLEMENTAL RESPONSE FOR MILLSTONE POWER STATION UNIT 3

1. DESCRIPTION OF APPROACH FOR OVERALL COMPLIANCE:

Dominion Nuclear Connecticut, Inc. (DNC) is in full compliance with regulations and regulatory requirements that are listed in U.S. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," including acceptance criteria for Emergency Core Cooling Systems (ECCS), 10 CFR 50.46(b)5, Long-Term Cooling. Corrective actions related to GL 2004-02 resulted in plant changes that are supported by completed analyses for Millstone Power Station Unit 3 (MPS3). Corrective actions that continue to evaluate downstream and chemical effects analyses are still in progress, supporting the changes and modifications that have been made in response to the GL 2004-02.

There is reasonable assurance that the MPS3 ECCS system can provide long-term cooling of the reactor core following a loss of coolant accident (LOCA). The ECCS system, including safety injection (SI), residual heat removal (RHR), the quench spray system (QSS), and the recirculation spray system (RSS) can remove decay heat so that the core temperature is maintained at an acceptably low value for the extended period of time required by the long-lived radioactivity remaining in the core. In addition, the QSS and RSS systems can operate to reduce the source term to meet the limits of 10 CFR Part 100.

A brief description of the approach taken to respond to GL 2004-02 is provided in the balance of this Section 1. The description includes information about methodology, modifications and their associated changes, and conservatisms. An overview of completed and in progress corrective actions is provided by Section 2 of this Attachment. Sections 3.A through 3.P provide more specific information regarding methodology and compliance.

A. METHODOLOGY OF ANALYSES:

The potential for adverse effects of post-accident debris blockage and debris-laden fluids to prevent the recirculation functions of the ECCS and Containment Spray System (CSS) was evaluated for MPS3. The evaluation considered all postulated design basis accidents 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, as modified by the NRC Safety Evaluation (NRC SE), dated December 6, 2004.

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

Downstream effects (components) analysis is complete, consistent with the methodology of WCAP-16406-P, Draft Rev. 1 "Evaluation of Downstream Sump Debris Effects in Support of GSI [Generic Safety Issue]-191," May 2006. A revision to this analysis consistent with the NRC approved methodology in WCAP-16406-P, Rev. 1, August 2007, is in progress.

Downstream effects analyses for the fuel and vessel are in progress, consistent with the methodology of WCAP-16793-NP, Rev. 0 "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007.

Chemical effects analyses are being performed that use a thorough assessment of existing literature and test data in conjunction with bench scale and reduced scale plant-specific testing.

Coatings are analyzed using a radius of 5-pipe diameters (5D) assigned to the Zone of Influence (ZOI) as detailed in Section 3.H for resolution of chemical effects and downstream effects. All coatings were assumed to be 10-micrometer particulate consistent with the GR and NRC SE.

B. MODIFICATIONS AND CHANGES:

The following plant modifications were installed.

- A new 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 psi of differential pressure and it has a strainer hole size of 1/16 inches, which is smaller than previous screen size of 3/32 inches.
- The start signal was changed for RSS pumps (which are the only ones that take their suction from the containment sump) during the spring 2007 refueling outage, as permitted by Amendment No. 233, (ADAMS Accession No. ML062220160). The modification changed the automatic start signal at approximately 660 seconds following the postulated accident to an automatic start when the 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.

The following changes were also made.

- Containment cleanliness standards have been defined and detailed in a station housekeeping procedure.
- Design controls have been put in place to require evaluation of potential debris sources in containment created by or adversely affected by design changes.
- 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.

C. CONSERVATIVISMS:

Detailed analyses of debris generation and debris transport were performed to ensure that a bounding quantity and mix of debris arrived at the strainer. Using the results of these analyses, conservative head loss testing was performed in both reduced-scale and large-scale test tanks to determine worst-case strainer head loss. A conservative basis is incorporated into the analyses, as discussed by items in the balance of this section.

- Debris generation analysis uses very conservative 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.
- 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, and thus 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.
- 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 MPS3 licensing basis 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.

- All unqualified coatings in containment are assumed to fail as transportable particulate.

- 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.

- 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.

- No credit was taken for accident-induced overpressure in calculation of net positive suction head (NPSH) margin for the ECCS pumps.

- 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 which have extremely low velocities during recirculation as shown in the computational fluid dynamics (CFD) analysis.

- A large strainer surface area combined with what is likely to be only localized break-induced turbulence will result 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 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 settling of debris has been credited in the downstream effects evaluation.

Additional conservatisms:

- 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
- 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, analysis conservatively assumes transport to the strainer following the break has no time delay.
- 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.
- 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.
- 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.

D. SUMMARY:

Based on the methodology, modifications, and conservatisms described above, there is a high confidence that the issues identified in GL 2004-02 have been addressed even with the uncertainties remaining (i.e., downstream effects analyses and chemical effects analyses).

2. GENERAL DESCRIPTION AND SCHEDULE FOR CORRECTIVE ACTIONS

The DNC letter dated November 15, 2007, describes a schedule and requests an extension beyond December 31, 2007, for corrective action milestones that are associated with GL 2004-02 for the performance of further chemical effects and downstream effects analyses. Completed corrective actions are summarized in Table 2-1. In progress corrective actions are summarized in Table 2-2.

Table 2-1: Completed Corrective Action Overview

Debris Generation and Debris Transport Analyses

Contains:

- break selection criteria,
- calculation of amount and type of debris generated for limiting breaks,
- breakdown of debris sizes,
- physical debris characteristics (i.e., density, fiber size, particulate size), and
- calculation of amounts of each debris type postulated to reach the ECCS strainer.

Analysis of Clogging and Wear for Components in ECCS Flow Stream Downstream of ECCS Strainer

These analyses use methodology in WCAP-16406, Draft Rev. 1 and include:

- a list of components susceptible to clogging that are in the ECCS flowpath downstream of the ECCS strainer,
- demonstration of clogging potential, and
- calculation of wear potential for susceptible components based on postulated debris bypass (i.e., all particulate is assumed to pass through the strainer for the component wear analysis).

Analyses of Water Holdup in Containment

Locations are identified where water will be blocked from reaching the ECCS strainer. Analyses for water holdup includes:

- holdup on component surface areas in containment,
- holdup on floors throughout containment, and
- holdup of water in the atmosphere.

Replacement ECCS Strainer Modification

This modification of the strainer is currently installed. The new strainer includes the following characteristics:

- surface area is approximately 5000 ft^2 versus an original screen surface area of approximately 240 ft^2,
- finned strainer was designed and manufactured by Atomic Energy of Canada Limited (AECL), and
- strainer is fully submerged prior to recirculation.

Table 2-1: Completed Corrective Action Overview

RSS Pumps Start Time Modification

This modification is complete. The modification changed the start time of RSS pumps to ensure that the strainer fully submerged prior to re-circulating water from the sump pool.

Chemical Precipitate Analysis and Effects

Analysis of chemical precipitate formation and the effect of those precipitates on ECCS strainer clogging is complete. This effort included the following:

- data review of WCAP-16530-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007,
- review of Integrated Chemical Effects Test (ICET) Reports,
- review of open literature data on aluminum corrosion and solubility, and
- comparison of test data to MPS3 expected post-LOCA plant conditions.

Table 2-2: In Progress Corrective Action Overview

Downstream Effects Analysis
An evaluation of downstream clogging and wear was completed for MPS3 in accordance with WCAP-16406-P, Rev. 0 and Draft Rev. 1. However, WCAP-16406-P, Rev. 1, was submitted in September 2007, and it includes revised guidance for the performance of downstream effects evaluations for components, including the reactor vessel and nuclear fuel. Also, WCAP-16793-NP Rev. 0, issued in May 2007, provides guidance on evaluation of blockage and chemical precipitate plateout in the reactor core and fuel and is currently undergoing NRC review and Safety Evaluation Report preparation. Consequently, revised downstream effects evaluations must be performed in accordance with the most recent WCAP guidance. The revised downstream effects evaluations are scheduled to be complete as soon as practical, commensurate with expedited corrective actions. (The estimate for this activity to be complete is by the end of the first quarter of 2008).
Chemical Effects Analysis
A chemical effects evaluation is in progress for MPS3 by the strainer vendor, AECL, to determine the potential for chemical precipitate formation, and bench top testing is being performed to validate evaluation assumptions. Reduced scale testing for chemical effects may also be necessary based on the results of bench top testing and/or other industry/regulatory testing results. Completion of the required chemical effects evaluation and testing is required to confirm that the replacement strainer installed at MPS3 is adequate to maintain net positive suction head (NPSH) margin for the ECCS pumps during long-term core cooling and to confirm that no further physical modifications are required. Completion of the chemical effects evaluation and testing and issuance of the technical report will be completed as soon as practical, commensurate with expedited corrective actions. (The current estimate for this activity's schedule is being expedited to achieve a May 31, 2008 completion date).

3. SPECIFIC INFORMATION REGARDING METHODOLOGY FOR DEMONSTRATING COMPLIANCE:

A. BREAK SELECTION

The objective of the break selection process is to identify the break size and location that presents the greatest challenge to post-accident sump performance. Sections 3.3 and 4.2.1 of the NEI 04-07 GR and the NRC SE provide the NRC-approved criteria to be considered in the overall break selection process in order to identify the limiting break.

The primary criterion used to define the most challenging break is the effect of generated debris on the estimated head loss across the sump strainer. Therefore, all phases of the accident scenario are considered for each postulated break location: debris generation, debris transport, debris accumulation, and resultant sump strainer head loss. Two attributes of break selection that are emphasized in the approved evaluation methodology cited above, and which can contribute significantly to head loss are: (1) the maximum amount of debris transported to the strainer; and (2) the worst combinations of debris mixes transported to and onto the strainer surfaces. Additionally, the approved methodology states that breaks should be considered in each high-pressure system that relies on recirculation, including secondary side system piping, if applicable.

The break selection evaluation was performed consistent with the approved SE methodology. Deviations from the staff-approved methodology are reasonable based on the technical basis provided below. Section 3.3.5 of the NRC SE describes a systematic approach to the break selection process including guidance for identification of break locations that rely on recirculation to mitigate the event:

Case No. 1:	Breaks in the reactor coolant system (RCS) with the largest potential for debris.
Case No. 2:	Large breaks with two or more different types of debris.
Case No. 3:	Breaks with the most direct path to the sump.
Case No. 4:	Large breaks with the largest potential particulate debris to insulation ratio by weight.
Case No. 5:	Breaks that generate a “thin-bed” (high particulate with at least a 1/8-inch fiber bed).

The spectrum of breaks evaluated for MPS3 is consistent with that recommended in the SE and is also consistent with regulatory position 1.3.2.3 of Regulatory Guide 1.82, Revision 3, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident”. The SE also describes a systematic approach to the break selection process, which includes beginning the evaluation at an initial location along a pipe, generally a terminal end, and stepping along in equal increments (5-feet increments), considering breaks at each sequential location.

The MPS3 plant configuration consists of four reactor coolant loops (1, 2, 3, and 4), each consisting of a steam generator, a reactor coolant pump, and reactor coolant piping. Each loop is contained in a concrete enclosure referred to as a cubicle. These four cubicles are essentially equivalent with respect to piping and equipment insulation.

The cubicles are essentially identical. This conclusion was shown by review of several drawing types, including piping isometrics, piping plan and sections, equipment locations, insulation, civil/structural, and equipment drawings. Insulation destruction was modeled for loop 2 since the worst-case break in loop 2 contains the largest total fibrous insulation volume and this break also produces the largest volume of Microtherm insulation. An additional analyzed break was selected in loop 1 based on proximity to the sump.

The expected size of coolant line break ZOIs is related to the physical configuration of the plant. The ZOIs essentially include the entire cubicle volumes at MPS3. The ZOIs were, therefore, relatively large for the impacted configuration. Consequently, a 5-feet incremental step-wise approach to the break selection process was not necessary, and not applied by DNC to analysis.

Breaks that are considered in the MPS3 analysis include the primary RCS piping that has the potential for breaks requiring mitigation by ECCS sump recirculation. Only piping 2 inches in diameter and larger was considered. This is consistent with Section 3.3.4.1 of the SE, which states that breaks less than 2 inches in diameter need not be considered. For MPS3, feedwater and main steam piping were not considered since recirculation flow is not required for mitigation of secondary-side breaks.

Insulation that is subject to destruction at MPS3 includes Transco fiberglass (in Blanket, Spiral Wrap and Encapsulated forms) and Microtherm (microporous insulation) inside the cubicles. NUKON™ low density fiberglass is also present because it has been used as replacement insulation in containment. This NUKON™ fiberglass is essentially identical to Transco fiberglass and is thus combined with the Transco fiberglass in the analyses associated with GSI-191. The debris generation evaluation using the cavity symmetry, as mentioned above, identified two break locations that provided limiting conditions for each of the 5 break selection criteria previously described:

- A crossover leg break at the A steam generator outlet - Break S1
- A crossover leg break at the B steam generator outlet - Break S2

These two breaks are nearly identical from an insulation debris generation standpoint. Neither break was shown to be significantly limiting. Analysis shows that the amounts and types of debris from these two breaks are reasonably equivalent. Proximity to the sump was found to be only a minor concern due to the assumed transport scheme of assuming all fines transport, 90% of small and large pieces subject to erosion transport, and all intact fiberglass debris will not transport. These breaks are limiting for all SE break selection criteria listed above.

Potential reactor vessel (RV) nozzle breaks could generate RV annulus insulation debris but would create only small amounts of insulation debris that could reach the strainer. Insulation mounted on the RV in the vicinity of the coolant loop nozzles is borated foamglass with Tempmat fibrous insulation. Neither of these insulation types is more detrimental to strainer head loss than the Transco fiberglass insulation. Below the nozzles, the neutron shield tank surrounding the RV is insulated with Transco reflective metallic insulation (RMI). An RV nozzle break creates insulation debris that collects below the RV. Transport of insulation out from below the RV would require the debris to rise greater than 10 feet before flooding to the containment floor. RMI debris would not likely transport out from below the RV due to the vertical rise required and would not create significant head loss even if it collected on the strainer. The foamglass and Tempmat insulation volume generated by an RV nozzle break is estimated to be far less than the volume of insulation generated by the evaluated breaks on the crossover legs. Thus, RV nozzle breaks are bounded by the selected breaks.

A review of smaller break LOCAs (i.e., less than 2 inches in diameter - defined in the SE) indicated a lower strainer head loss than for the larger break LOCAs analyzed. Smaller breaks would generate substantially less debris, might not activate the QSS thereby reducing debris transport to the strainers, and would result in reduced ECCS flow rates (with a corresponding reduction in strainer head loss) to the core due to flow resistance at the break. The sump pool water level would be somewhat lower for small breaks than for the large breaks, which would reduce the NPSH margin. Reductions in debris generation and transport associated with small breaks have a far more influential effect on strainer head loss than would the reductions in NPSH margin. Additionally, the limiting water level for MPS3 used in the NPSH and suction line flashing analysis for the RSS pumps is for a small break LOCA (SBLOCA) of 2 inches.

B. DEBRIS GENERATION / ZONE OF INFLUENCE (EXCLUDING COATINGS)

The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; (2) the amount of debris generated by the break jet forces; and (3) the size characteristics of the debris. Sections 3.4 and 4.2.2 of the GR and the NRC SE provide methodology considered in the ZOI and debris generation analytical process.

The GR baseline methodology incorporates a spherical ZOI based on material damage pressures. The size of the spherical ZOI for a material, if known, is based generally on the experimentally-deduced destruction pressures as they relate to the American National Standards Institute/American Nuclear Society (ANSI/ANS) 58.2, 1988 standard for a freely expanding jet, titled "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture." Once the most limiting (largest) ZOI is established, the types and locations of all potential debris sources (insulations, coatings, dirt/dust, fire barrier materials) are identified using plant-specific drawings, specifications, and walkdown reports. The amount of debris generated is then calculated based on the amount of materials within the most limiting ZOI. Section 4.2.2 of the SE discusses proposed refinements to the GR methodology that would allow application of debris-specific ZOIs. This refinement allows the use of a specific ZOI for each debris type identified. Using this approach, the amount of debris generated within each ZOI is calculated, and then added to arrive at a total debris source term. The NRC staff concluded in its SE that the definition of multiple, spherical ZOIs at each break location corresponding to damage pressures for potentially affected materials is an appropriate refinement for debris generation. As discussed in Section 4.2.2 of the SE, the NRC staff accepted the application of these proposed refinements for PWR sump analyses for GL 2004-02 corrective actions.

The MPS3 evaluation of debris generation and ZOI evaluation is consistent with the approved methodology. MPS3 applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE, which allows the use of debris-specific spherical ZOIs. As discussed above, using this approach the amount of debris generated within each ZOI is calculated, and the individual contributions from each debris type are summed to arrive at a total debris source term. Section 3.4.2.2 of the SE provides guidance for selection of a ZOI. The entries from the SE relevant to the material types referenced for MPS3 show the following:

Table B-1: Revised Damage Pressures and Corresponding Volume-Equivalent Spherical ZOI Radii

Insulation /Coating Types	Destruction Pressure (psig)	ZOI Radius/Break Dia. (R/D)
Unjacketed NUKON™ / Jacketed NUKON™ with standard bands	6	17.0
Min-K	2.4	28.6

The debris generation calculation identifies the following types of insulation within the ZOIs in the MPS3 containment: Transco fiberglass, NUKON™, and Microtherm. Not all of these insulation types are specifically identified in the SE. The Transco fiberglass insulation is treated as a low-density fiberglass (LDFG) equivalent to NUKON™. Because no ZOI or test data was referenced in the SE for Transco fiberglass, the relatively large 17D radius was assumed for this insulation material. The Transco metallic cassettes and stainless steel jacketing would provide significant protection to the fiberglass and reduce actual destruction. These are conservative factors that were not specifically credited for debris generation analysis at MPS3. Similarly for Microtherm, the ZOI of 28.6 for Min-K (listed in Table 3-2 of the NRC SER) was used. This is reasonable because both Min-K and Microtherm are granular insulation with very small particle sizes and no specific ZOI or test data was referenced in the SE for Microtherm. Also, the SE-referenced ZOI for Min-K is the largest of all the insulation materials tested. Microtherm is only used at discrete locations on the MPS3 loop piping at the pipe whip bumpers. Use of the 28.6D ZOI includes all of the Microtherm in the cubicles and thus is conservative. No destruction testing of debris was used to determine ZOIs beyond values referenced in the NRC SE.

No calcium silicate insulation is used in containment at MPS3. This significantly reduces the potential for formation of calcium phosphate precipitate at MPS3, and the resultant negative effects on strainer head loss. For a more detailed review of this issue, see the Chemical Effects evaluation in Section O of this response.

A summary of the expected LOCA generated debris is included in the debris generation calculation for each of the breaks analyzed. A reduced summarization of the expected insulation debris generation quantities is provided in Table B-2 below:

Table B-2: Summary of Expected Debris Generation Quantities

Debris Type	Break S1	Break S2	Break S3
Transco Encapsulated Fiberglass (ft^3)	1076	1200	428
Transco Blanket Fiberglass (ft^3)	124	107	36
Transco Spiral Wrap Fiberglass (ft^3)	19	17	0
5% Margin—Total Fiberglass (ft^3)	61	66	23
Microtherm (ft^3)	1.1	1.1	0
5% Margin—Microtherm (ft^3)	0.1	0.1	0

As noted in Table B-2, an additional 5% of fiber insulation and 5% of Microtherm was added for evaluation purposes for conservatism. The physical radius of a 17D ZOI around a 31-inch pipe break would be approximately 44 feet. Such a sphere would encompass essentially the entire affected cubicle. Because of this, the quantities of debris generated are limited by the cubicle walls rather than the size of the ZOI.

In general, the debris generation evaluation for the LOCA-generated insulation debris is conservative because MPS3 consistently used either SE-accepted practices and values, or conservative approaches.

Other sources of debris at MPS3 include coatings debris, latent debris, chemical effects precipitates, and miscellaneous debris such as signs and tags. The coating debris generation is discussed separately in Section H, latent debris is discussed in Section D, and chemical effects precipitates are discussed in Section O. Foreign debris (total estimated surface area 872 ft^2) was quantified by containment walkdown and includes signs, placards, tags, stickers, and glass.

The debris generation evaluation was performed in a manner consistent with the approved SE methodology. MPS3 applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE, which allows use of debris-specific spherical ZOIs. Where appropriate, material-specific damage pressures and corresponding ZOI radius/break diameter ratios were applied as shown in Section 3.2-1 of the NRC SE. For insulation types not found in the SE, MPS3 applied reasonable, or conservative, substitute values for insulation properties and provided adequate technical justification for these positions.

Significant Conservatisms in the Debris Generation Analysis:

There are several substantial conservatisms in the debris generation analysis including the following:

- Nearly 90% of the Transco fiberglass insulation at MPS3 is encapsulated in welded stainless steel canisters providing substantially more protection than the uncovered fiberglass used as part of the basis for establishing the 17D ZOI used for fiberglass insulation. The remainder of the fiberglass insulation in the MPS3 containment is jacketed in stainless steel, which also provides more protection than uncovered fiberglass.

- The spherical ZOI model significantly over predicts the volume of fibrous insulation expected to be dislodged by an actual pipe break.

- No credit is taken for the partial leak-before-break analysis at MPS3 for the reactor coolant piping that is approved by the NRC. Instead, the debris generation analysis assumes an instantaneous pipe break and significant pressure wave dislodge insulation throughout the ZOI.

- All unqualified coatings and all qualified coatings within the coatings ZOI are assumed to fail as transportable particulate and arrive at the strainer for MPS3. No credit is taken for coating remaining intact, failing as non-transportable chips, or settling prior to arrival at the strainer. It is far more likely that coating will fail as a mix of piece sizes and that very little will transport to the strainer.

- All latent debris found in containment is assumed to enter the sump pool water column and thus be available for transport. Latent debris is spread on many surfaces throughout containment and it is unlikely that spray flows, break flows, condensation, and pool water flows will dislodge more than a fraction of this debris.

C. DEBRIS CHARACTERISTICS

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss. The specification of debris characteristics is important to analytical transport and head loss evaluations and to the specification of surrogate materials for head loss testing. The potential LOCA-generated sources of debris for the MPS3 containment include debris from two types of insulation: Transco fiberglass and Microtherm. The potential quantities of debris from these insulation types were shown on Table B-2 in the Debris Generation/ZOI section above. Besides the insulation sources, other potential debris sources include latent fiber, latent particulate, foreign material debris, and coatings debris.

Transco Fiberglass Insulation:

A LOCA inside the MPS3 containment could generate substantial quantities of Transco fiberglass insulation debris (encapsulated, blanket type, and spiral wrap) as well as small quantities of NUKON™ insulation that have been used to replace damaged Transco fiberglass insulation. MPS3 adopted the radius of 17D for the postulated ZOI as discussed in Section B above. The assumed size distribution of 8 percent for fines, 25 percent for small exposed pieces, 32 percent for large exposed pieces, and 35 percent for debris still encased in jacketing, was developed from the confirmatory research guidance in the SE appendices.

Per the confirmatory Appendix V in the SE, Transco fibrous insulation is very much like NUKON™, which has been tested and validated extensively with noted parameter application limits. Therefore, it is reasonable to extend the validation for NUKON™ fibrous insulation debris to Transco fibrous insulation debris. These two insulations are so similar that their associated densities and specific surface areas have been treated identically.

MPS3 assumes that 100 percent of the fiberglass fines would transport to the strainers and that the transport fractions of the larger fiberglass debris could be predicted using the floor tumbling and lift velocities method in their containment pool computational fluid dynamics (CFD) transport analysis. MPS3 uses transport velocities taken from NUREG/CR-6772, "GSI-191: Separate-Effects Characterization of Debris Transport in Water," August 2002. The incipient tumbling velocity was conservatively established as 0.12 ft/s for all pieces of exposed fiberglass debris independent of size. The assumed lift velocities of 0.25 ft/s for small and large pieces of exposed debris are conservatively based on a two-inch high curb around the containment sump for Transco Thermal Wrap, which is used at MPS3. These velocities are valid for relatively uniform and non-turbulent flows. MPS3 used the GR recommendation for NUKON™ head loss characteristics and applied them to the nearly identical Transco fiberglass insulation. The bulk and material densities are 2.4 lb_m/ ft^3 and 159 lb_m /ft^3 respectively. The fibers were assumed to be nominally 5.5 μm in diameter with a specific surface area of 218,000/ft [ft^2/ft^3].

Microtherm:

A LOCA inside the MPS3 containment could generate only very small quantities of Microtherm insulation debris. MPS3 adopted the radius of 28.6D for the postulated ZOI as discussed in Section B above. The assumed size distribution is 100 percent small fines that will completely transport to the sump strainer. Thus, there is no need to specify debris transport characteristics for Microtherm insulation.

Head loss properties are not available for the Microtherm insulation specifically used at Millstone. Debris head loss for the strainer design at MPS3 was determined via testing rather than by head loss correlation with the NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," October 1995. Consequently, a determination of specific head loss characteristics for Microtherm insulation was unnecessary.

Latent Debris:

MPS3 used head loss debris characteristics for fibrous latent debris that were recommended in NUREG/CR-6877, "Characterization and Head-Loss Testing of Latent Debris from Pressurized Water Reactor Containment Buildings," July 31, 2005. MPS3 assumed the bulk and material densities were 2.4 lb_m/ft^3 and 93.6 lb_m/ft^3, respectively. The fibers were assumed to be nominally 5.5 μm in diameter with a specific surface area of 171,000/ft [ft^2/ft^3]. These values are consistent with the bulk fibrous insulation in containment.

For latent particulate, MPS3 adopted the recommendations from Appendix V of the SE. For a bulk density, the SE recommended a range from 63 to 75 lb_m/ft^3, while MPS3 assumed 65 lb_m/ft^3. The SE recommended a specific gravity of 2.7 for the material density, which corresponds to the 168.6 lb_m/ft^3 used by MPS3. MPS3 used the SE-recommended specific surface area of 106,000/ft [ft^2/ft^3].

Because all latent debris was assumed to transport completely to the sump strainers, no transport characteristics need to be specified.

Latent Debris is further discussed in Section D of this report.

Foreign Debris:

MPS3 accounts for tags, labels and other materials by assignment of 655 ft^2 of sacrificial area of the sump strainer. The total surface area of foreign debris, including tags, labels, and stickers (872 ft^2) was established based on a plant walkdown to quantify foreign material. Per the NRC SE, Section 3.5.2.2.2, the total area of strainer blockage due to stickers, tape, and other similar material should be 75% of the total wetted surface area of these materials. Thus, a sacrificial surface area of 655 ft^2 is included in the strainer design to account for potential blockage by tags, labels, stickers, placards, and glass that are considered transportable. Therefore, because 100 percent transport of foreign debris is assumed, debris characteristics for foreign debris are not specified.

D. LATENT DEBRIS:

Latent debris characteristics are discussed in Section C of this report. The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump strainer head loss.

MPS3 performed an evaluation of the potential sources of latent debris using guidance provided by the GR and the NRC SE. Latent debris is that debris in containment before a postulated LOCA occurs, as opposed to debris that would be generated during a LOCA. Such debris could include fibers, particulates (e.g., dust and dirt), and other miscellaneous material. The NEI GR provides recommendations for quantifying the mass and characteristics of latent debris inside containment. The following baseline approach is recommended:

- estimate the total area, including both horizontal and vertical area contributions,
- survey/sample the containment to determine the mass of debris present,
- define the debris composition and physical properties,
- determine the fraction of total area that is susceptible to debris buildup, and
- calculate the total quantity and composition of debris.

Since MPS3 has an expected high fiber and particulate load on the sump strainer following a LOCA, the additional contribution to sump strainer head loss from latent debris is relatively small. Thus, approximations of surface areas from existing calculations and drawings were used to arrive at a conservative but reasonable approximation of the total surface area in containment subject to latent debris accumulation and transport via either accident generated steam and water jets, containment spray impact, break flows, or washdown.

Surfaces in the MPS3 containment were divided into vertical and horizontal surface categories, and the surface area of each category was estimated. The containment was surveyed to determine the mass of debris present.

For each area category, at least three latent debris samples were taken and weighed. An area of 2 ft^2 was sampled at each location. The latent debris mass for each surface category was computed using the total area for the surface category and the average mass of debris per unit area derived from the sampling. The total mass of latent debris was then obtained by summing the masses computed for each surface category. MPS3 did not perform a physical characterization of the samples. Instead, as stated in the GR, MPS3 "...assumed the composition and physical properties of the debris, using conservative values..." [pages 3-35], and specified that the "...fiber contributes 15 percent of the mass of the total estimated inventory..." as recommended by the SE.

Two latent debris surveys were taken during two MPS3 refueling outages. The latent debris masses obtained from these two sets of data were 567 lb_m from the fall 2005 outage 3R10 and 344 lb_m from the spring 2007 outage 3R11. The quantitative estimates of the surface areas for each surface area category are presented in the Table D-1, below.

Table D-1: Latent Debris Sample Results

Surface Category	Total Surface Area (ft^2)	Fall 2005 Total Latent Debris (lb_m)	Spring 2007 Total Latent Debris (lb_m)
Painted Steel	325,961	179	143
Concrete	122,399	40	54
Insulated Surfaces	16,254	7	0
Cable Trays	14,465	33	5
Concrete Floors	19,970	26	11
Structural Steel	113,444	175	112
Piping/Conduit	27,261	57	9
Ductwork	7,802	20	4
Major Equipment	3,816	6	1
Floor Grating (w/ I-beams)	9,300	24	5
Total Mass of Latent Debris		567 lb_m	344 lb_m

On the basis of the two surveys and the calculated total masses, MPS3 selected 567 lb_m as the value to be used for the latent debris mass that allows some margin. Strainer design testing used 85 lb_m of latent fiber and 482 lb_m of latent particulate. Despite the variability of the two survey-based estimates of total latent debris mass, the estimate of 567 lb_m is reasonable and conservative. That conclusion can reasonably be supported in evaluating the survey results and calculations because it equals the maximum of the two sample-based mass loadings.

The latent debris that was sampled at MPS3 was not characterized. The assumption is made that 15 percent of the debris is latent fiber, and that 85 percent is latent particulate. This assumption is consistent with findings of a study of latent debris in four plants, and is consistent with the guidance provided in the NRC SE, page 50.

Technical Justification of Assumptions: *(Latent Debris)*

Assumption: The average sample mass found for each category during latent debris sampling represents the mass over the entire surface area included in that category.

Basis: This assumption allows use of sampling to arrive at an estimate of the latent debris total in containment. Since latent debris is such a small part of the total debris load at MPS3, this assumption provides a reasonable basis for estimating the amount of latent debris.

Assumption: All vertical and horizontal surfaces in containment fall into one of the categories listed in Table D-1.

Basis: The categories were selected based on surfaces most prevalent throughout containment and represent the vast majority of all surfaces in containment.

Assumption: Half of the structural steel surface area is vertical.

Basis: Structural steel in containment for latent debris collection is taken from the heat sink calculation that includes the surface area of all structural steel in containment. The surface area total includes the entire perimeter of the structural steel. Much of the structural steel is I-beams, channels and angles that have significant vertical surface area even when oriented horizontally. Orientation of each piece of structural steel in containment was not determined for the calculation of surface area for latent debris collection. Some of the steel is oriented vertically and thus has very little horizontal surface area. Because this calculation determines only an approximate area, and because much of the structural steel will be unable to collect debris due either to position or orientation or both, it is reasonable to assume that half of the structural steel surface area is vertical.

Assumption: All conduit is horizontal.

Basis: Horizontally oriented surface areas generally collect more latent debris than vertically oriented surface areas. Assuming all conduit is horizontal avoids the need to determine orientation and is conservative since only horizontal conduit is sampled.

Assumption: Only top half of piping and conduit collects debris.

Basis: Bottom half of piping and conduit is vertical or inverted and the amount of debris collected is negligible.

Assumption: Inverted surfaces (i.e., containment dome) collect no debris.

Basis: Debris will tend to fall from inverted surfaces.

Assumption: Containment spray washdown coverage is 100% and debris on surfaces covered by other surfaces will end up at the sump due to washdown and water deflection.

Basis: These assumptions ensure that all latent debris found is assumed to go to the containment sump pool.

Assumption: Surface areas of major items can be adequately estimated using common geometrical shapes and dimensions from plan drawings.

Basis: This simplifies the calculation and provides generally conservative surface area values—leads to larger quantities of calculated latent debris.

Assumption: MPS3 accounts for tags, labels, tape and other materials by assignment of 655 ft^2 of sacrificial area of the sump strainer.

Basis: This sacrificial area was arrived at by a plant walkdown to determine the area of tags and labels on components in the MPS3 containment. This methodology is a conservative approach because it uses actual values from the containment, and not all tags and labels would migrate to the sump.

E. DEBRIS TRANSPORT:

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers. Generally speaking, debris transport would occur through four major mechanisms:

- blowdown transport - the vertical and horizontal transport of debris throughout containment by the break jet;
- washdown transport - the downward transport of debris due to fluid flows from the containment spray and the pipe rupture;
- pool-fill transport - the horizontal transport of debris by break flow and containment spray flow to areas of the containment pool that may be active (influenced by recirculation flow through the suction strainers) or inactive (holdup or settling volumes for fluid not involved in recirculation flow) during recirculation flow; and

- containment pool recirculation transport - the horizontal transport of debris from the active portions of the containment pool to the suction strainers through pool flows induced by the operation of the ECCS and CSS in recirculation mode.

Through the blowdown mechanism, some debris would be transported throughout the lower and upper containment. Through the washdown mechanism, a fraction of the debris in the upper containment would be washed down to the containment pool. Through the pool fill-up mechanism, debris on the containment floor would be scattered to various locations, and some debris could be washed into inactive volumes that do not participate in recirculation. Any debris that enters an inactive pool would tend to stay there, rather than being transported to the suction strainers. Through the recirculation mode, a fraction of the debris in the active portions of the containment pool would be transported to the suction strainers, while the remaining fraction would settle out.

The debris transport methodology is described in the debris transport calculation. MPS3 used logic trees to calculate the transport of debris from the ZOI of each analyzed pipe rupture to the sump strainers, considering debris transport phenomena associated with the blowdown, washdown, pool fill, and recirculation processes. The logic trees were based upon a generic model recommended by NEI 04-07. DNC quantified these logic trees for MPS3 to calculate transport fractions for the following types of debris:

- small and large pieces of fiberglass debris; and
- intact debris covers/jacketing.

DNC did not use logic trees to compute the transported quantities for small fines, coatings, and latent debris, since these types of debris were generally assumed to fully transport to the sump strainers.

The debris transport methodology generally follows guidance from NEI 04-07, using assumptions from both the baseline methodology as well as analytical refinements from Section 4.0. In particular, MPS3 applied an analytical refinement to analyze debris transport during the recirculation phase of a LOCA by using FLUENT CFD code to compute the flow in the containment pool. The paragraphs in the balance of this section discuss the transport methodology in detail.

A CFD analysis was performed for both the original and the replacement sump strainer designs (installed in spring 2007).

Blowdown Transport:

The blowdown transport analysis was based on the methodology from NUREG/CR-6369 (the Drywell Debris Transport Study that was performed for boiling-water reactors (BWRs)), Section 3.6.3.2 of the GR, and Appendix VI of the NRC SE. In light of the complexity of modeling the distribution of steam and air flows in containment following a pipe rupture, MPS3 used the simplified methodology for blowdown transport presented in Section 3.6.3.2 of the GR. Based upon this methodology, all debris (both small and large pieces) was conservatively postulated to fall directly into the containment pool rather than being blown into the upper containment. Although the GR does not specifically state that all fibrous debris should be modeled as directly falling into the containment pool, MPS3 conservatively took this position. This approach is reasonable based upon the GR guidance that large debris may be modeled as falling directly into the containment pool and upon the expectation that the majority of the small debris blown into the upper containment would eventually be washed down to the containment pool.

This approach for analyzing blowdown transport is conservative for the purpose of evaluating debris transport to the sump strainers. In particular, although the assumption that all post-accident debris directly enters the containment pool is not realistic, it ensures that no credit is taken for the capture and sequestration of debris at higher elevations of containment. As a result, the quantity of debris available for transport to the sump strainers is conservatively maximized.

Washdown Transport:

There is a potential for some small pieces of debris to adhere to wet surfaces. However, since MPS3 assumed that 100 percent of the post-LOCA debris would be deposited directly into the containment pool, a detailed washdown analysis is not necessary. In general, the location where debris enters the recirculation pool may have a strong influence on the debris transport fraction. However, based upon the incorporation of significant conservatism in the MPS3 transport analysis, primarily the assumption that all post-accident debris has already been blown directly into the containment pool, and the use of the highest continuous velocity between the pipe break and the containment sump to compute debris transport fractions in the containment pool during recirculation (this methodology is described further below), a detailed washdown analysis is not necessary for MPS3.

Pool-Fill Transport:

MPS3 did not create a detailed model of debris transport resulting from shallow, high velocity sheeting flows that may occur during the pool fill-up phase. The debris transport analysis states that the containment has no significant inactive holdup volumes other than the reactor cavity and normal containment building sump. In order for debris to be trapped in the reactor cavity, the break location target material would have to be within the primary shield wall (e.g., a reactor vessel nozzle break impinging on reactor vessel or neutron shield tank insulation), considering the permanent physical obstructions in containment that include the shield wall and the refueling canal. Debris transport into the reactor cavity through pool fill-up would be minimal because there is no path from the containment sump pool to the reactor cavity at the minimum flood elevation. On this basis, the potential for debris retention at holdup points or inactive pool volumes is insignificant with regard to the transport of debris to the containment recirculation sump. Importantly, in both cases, the reactor cavity holdup volume and the normal containment building sump, the calculations take no credit for debris holdup.

Neglect of debris settling in inactive pool volumes within the post-LOCA containment pool is appropriate because it maximizes the quantity of debris available to transport to the sump strainers during the recirculation phase of an accident. The bottom of the MPS3 replacement strainers is located approximately 7 inches above the floor of containment (as opposed to being below the surrounding containment floor grade in the sump pit). Due in part to the strainers' raised configuration, there is little potential for significant quantities of debris beyond what is already accounted for in the existing analysis, to transport to and accumulate on the sump strainers during the filling of the containment pool.

Containment Pool Recirculation Transport:

MPS3 computed flow velocity and turbulence fields in the containment pool during the recirculation phase of a LOCA with the aid of the FLUENT CFD code. The CFD input decks physically model the MPS3 containment from the containment floor level (plant elevation of -24.5 feet) to the minimum post-LOCA containment water level (plant elevation -20.17 feet). Major containment obstructions were included in the CFD model, including the reactor, reactor head stand, various tanks, heating, ventilating, and air conditioning (HVAC) equipment, trisodium phosphate (TSP) baskets, and support columns. The CFD analysis is based upon the replacement strainer (installed in spring 2007). As described in more detail below, MPS3 compared the flow velocities resulting from the CFD simulation to experimentally generated debris transport thresholds to determine the quantities of debris reaching the containment recirculation sump. All fines and particulate are assumed to transport independent of CFD analysis results.

Pool Recirculation Transport Scenarios Analyzed:

Using CFD, DNC analyzed four separate pool recirculation transport scenarios, as summarized in Table E-1 below.

Table E-1: Pool Recirculation Debris Transport Scenarios

Scenario	ECCS Trains Running	Pipe Break	Description of Pipe Break
1	2	S1	A double-ended guillotine break at the 31-inch Crossover Leg nozzle to Steam Generator A.
2	1	S1	A double-ended guillotine break at the 31-inch Crossover Leg nozzle to Steam Generator A.
3	2	S2	A double-ended guillotine break at the 31-inch Crossover Leg nozzle to Steam Generator B.
4	2	S4	A double-ended guillotine break at the 31-inch Crossover Leg nozzle to Steam Generator D.

Once recirculation begins, the flow through each of these breaks is contained within the surrounding steam generator cubicle until it flows into the containment pool at elevation -24 feet 6 inches. The justification for analyzing the four scenarios listed in Table E-1 is summarized in Table E-2 below.

Table E-2: MPS3 Justification for the Four Analyzed Recirculation Transport Scenarios

Scenario	Justification
1	Chosen due to proximity of Break S1 to the sump strainer and large quantity of debris.
2	Chosen to consider Break S1 for single train operation.
3	Chosen because Break S2 generates the largest quantity of debris.
4	Chosen due to proximity of Break S4 to the sump strainer for CFD analysis to determine impact of debris flowing toward sump from end opposite break S1.

No debris transport analysis was performed for Break S3, which is a 14-inch alternate break located at the crossover leg nozzle to Steam Generator A (i.e., the same location as Break S1). The justification for not analyzing recirculation pool transport for this break is that the quantity of debris transported to the sump strainer would be bounded by the four scenarios that were analyzed, in particular by Scenario 1 above, since the 31-inch S1 break at the same location would generate significantly more debris for similar but slightly more severe pool transport conditions.

Debris Transport Metrics:

A summary of the metrics used to analyze debris transport during containment pool recirculation is provided in Table E-3 below:

Table E-3: Metrics Used for Analyzing Debris Transport During Recirculation

Debris Type	Incipient Tumbling Velocity (ft/s)	Curb Lift Velocity (ft/s)
Transco Thermal Wrap Low Density Fiberglass	0.12	0.28

For the Transco Thermal Wrap low-density fiberglass debris, MPS3 used both the incipient tumbling velocity metric and the curb lift velocity metric based upon experimental data reported in NUREG/CR-6772. The curb lift velocity metric is based upon the experimental results using a 2-inch curb. The replacement strainer at MPS3 is approximately 7 inches off the floor and has no continuous curb to lift over and thus this lift velocity is conservative. The available literature does not include curb lift velocities for insulation covers, but because the size and density of RMI foils makes them resistant to lifting over curbs, larger and/or denser insulation jacketing covers could not be transported up onto the strainer surface that sits approximately 7 inches above the floor. The assumption that insulation jacketing cannot be lifted over a curb is acceptable because (1) from the discussion in NUREG/CR-3616, "Transport and Screen Blockage Characteristics of Reflective Metallic Insulation Materials," January 1984, the 0.7 ft/s incipient tumbling velocity appears to be associated with a sliding motion, indicating that tumbling is not the expected transport mechanism for this type of debris, and (2) a much higher velocity of 1.8 ft/s is necessary to move insulation covers with their concave side down. Therefore, debris transport of insulation jacketing and covers is neglected.

The debris transport calculation did not employ a turbulent kinetic energy (TKE) metric to specify the intensity of flow turbulence as an approach for crediting the settling of fine debris.

Debris Interceptors and Curbs:

The previous containment recirculation sump screen surface area was nominally 2 ¼ inches above the floor due to its framing supports. This framing effectively functioned as a curb. The replacement strainer does not include a curb. However, the replacement strainer is located approximately 7 inches above the surface of the containment floor. Raising the strainer off of the floor produces an effect similar to the previous curb. There is a potential for a debris "ramp" to accumulate at the base of the replacement strainers and formation of a debris ramp could reduce the lift velocity required to transport debris over a curb or gap and limit the amount of debris that could be sequestered. However, due to the raised design of the replacement strainers and the significant degree of conservatism in the debris transport calculation, the assumption of a debris curb being present around the sump strainer is acceptable, even without consideration of ramping effects. No debris interceptors were installed at MPS3.

Fibrous Debris Erosion:

The debris transport analysis recognized that, while large or small pieces of exposed fibrous debris may not be transportable under low velocity flow conditions, erosion of settled pieces of fibrous debris should be considered. All else being equal, the fibrous debris erosion rate tends to be larger in shallower pools than in deeper pools. Section III.3.3.3 of Appendix III to the NRC SE suggests that, in lieu of specific erosion data, 90 percent of the small and large pieces of fibrous debris analyzed as settling in the containment pool should be considered to erode into fines over a 30-day period. The SE position was based on data in NUREG/CR-6773, "GSI-191: Integrated Debris-Transport Tests in Water Using Simulated Containment Floor Geometries," December 2002, for which one of the long-term integrated transport tests was performed at pool velocities of approximately 0.15 ft/s in the vicinity of the simulated pipe break and sump screen. Flow velocities in the MPS3 containment pool are significantly lower than those in the applicable test from NUREG/CR-6773. The assumption of 90 percent erosion was conservatively applied to MPS3. Large pieces of debris with intact jacketing are not considered to erode, which is consistent with the position taken in the NRC SE.

Microtherm Insulation:

MPS3 assumes that Microtherm insulation would become 100 percent fines if located within the ZOI for an analyzed pipe rupture. This assumption is based upon guidance provided in the GR, which recommends that a size distribution of 100 percent fines be assumed absent experimental data. MPS3 did not generate logic trees for modeling the transport of Microtherm fines, since 100 percent of fine debris was modeled as transporting to the containment recirculation sump. The assumption of 100 percent fines is a significant conservatism.

Latent Particulate Debris:

The MPS3 debris transport calculation assumes 100% transport of latent debris to the strainer and assumes that all of the latent fiber is in the form of individual fibers. This is conservative in light of the guidance for transport of latent debris provided in the NRC SE. Per the SE, not all particulate latent debris transports to the containment recirculation sump. Both NUREG/CR-6877 and Section 3.5.2.3 of the SE on NEI 04-07 state that 22 percent of the latent particulate debris mass determined from raw samples taken above the recirculation pool flood level may be assumed to be non-transportable and that 7.5 percent of the latent particulate debris may be assumed to penetrate the sump strainer without contributing to debris bed head loss. Using 100% transport of latent particulate is, thus, conservative.

Computational Fluid Dynamics Analysis:

MPS3 used CFD to simulate the flow field in the MPS3 containment pool during sump recirculation as an input to the debris transport calculation. The CFD analysis using FLUENT was performed by RWDI, Inc., a subcontractor to Sargent and Lundy.

The NRC staff reviewed a similar CFD analysis done for Millstone Power Station Unit 2, which is described in the Millstone Power Station Unit 2 Audit Report (ADAMS Accession No. ML072290550), and found the analysis to be acceptable. CFD is a simulation technique in which the standard equations of fluid flow are numerically solved using a computer.

To determine transport of debris, the highest continuous velocity between the break location and the containment recirculation sump was compared to the experimentally derived tumbling transport metrics. This is conservative for determining transport fractions since in reality most post-accident debris would be subjected to velocities that are less than the maximum velocity. Similarly, the maximum velocity at the perimeter of the sump was compared to the curb lift velocity metric. This comparison is also conservative since this comparison overestimates the quantity of debris that is capable of being carried over the curb. Turbulence and debris ramping that could increase the opportunity for debris to climb over a curb were neglected because of the significant conservatisms throughout the transport analysis.

Overall Transport Results:

The debris transport calculation provides results for each CFD scenario, both in terms of the debris transport fractions and the total quantities of debris that arrive at the containment recirculation sump. These quantities are summarized in the tables below. The debris transport results for CFD Scenarios 1 and 4 are identical. CFD Scenarios 1 and 4 both model a 31-inch double-ended crossover pipe rupture at the steam generator nozzle in cubicle 1 and cubicle 4, respectively (Breaks S1 and S4), which are both in close proximity to the ECCS sump. CFD Scenarios 1 and 2 both use Break S1, however, for Scenario 1, two trains of ECCS are assumed to be operating, and for Scenario 2, only one train is assumed to be operating. CFD Scenario 3 uses Break S2, which produces the highest volume of insulation, but which is relatively remote from the ECCS sump.

No credit was taken for debris interceptors since no specific debris interceptors were installed as part of the resolution of GSI-191.

No credit was taken for settling of fine debris in the transport calculation. This is a significant conservatism due to the compartmentalized containment and the many and varied surfaces upon which fine debris is likely to settle.

Table E-4: Debris Transport Calculation Results for CFD Scenario 1 (Break S1)

Debris Type	Transport Fraction	Quantity Transported
Transco Thermal Wrap	0.59	719.2 ft^3
Margin for Thermal Wrap	0.59	36.0 ft^3
Microtherm	1.0	1.1 ft^3
Margin for Microtherm	1.0	0.1 ft^3
Qualified Steel Coatings	1.0	8.9 ft^3
Qualified Concrete Coatings	1.0	1.54 ft^3
Unqualified Coatings	1.0	10.5 ft^3
Margin for Coatings	1.0	2.1 ft^3
Latent Fiber	1.0	85 lb_m
Latent Particulate	1.0	482 lb_m
Foreign Material Allowance	1.0	655 ft^2

Table E-5: Debris Transport Calculation Results for CFD Scenario 2 (Break S1)

Debris Type	Transport Fraction	Quantity Transported
Transco Thermal Wrap	0.59	719.2 ft^3
Margin for Thermal Wrap	0.59	36.0 ft^3
Microtherm	1.0	1.1 ft^3
Margin for Microtherm	1.0	0.1 ft^3
Qualified Steel Coatings	1.0	8.9 ft^3
Qualified Concrete Coatings	1.0	1.54 ft^3
Unqualified Coatings	1.0	10.5 ft^3
Margin for Coatings	1.0	2.1 ft^3
Latent Fiber	1.0	85 lb_m
Latent Particulate	1.0	482 lb_m
Foreign Material Allowance	1.0	655 ft^2

Table E-6: Debris Transport Calculation Results for CFD Scenario 3 (Break S2)

Debris Type	Transport Fraction	Quantity Transported
Transco Thermal Wrap	0.59	781.2 ft^3
Margin for Thermal Wrap	0.59	38.9 ft^3
Microtherm	1.0	1.1 ft^3
Margin for Microtherm	1.0	0.1 ft^3
Qualified Steel Coatings	1.0	8.9 ft^3
Qualified Concrete Coatings	1.0	1.54 ft^3
Unqualified Coatings	1.0	10.5 ft^3
Margin for Coatings	1.0	2.1 ft^3
Latent Fiber	1.0	85 lb_m
Latent Particulate	1.0	482 lb_m
Foreign Material Allowance	1.0	655 ft^2

Table E-7: Debris Transport Calculation Results for CFD Scenario 4 (Break S4)

Debris Type	Transport Fraction	Quantity Transported
Transco Thermal Wrap	0.59	719.2 ft^3
Margin for Thermal Wrap	0.59	36.0 ft^3
Microtherm	1.0	1.1 ft^3
Margin for Microtherm	1.0	0.1 ft^3
Qualified Steel Coatings	1.0	8.9 ft^3
Qualified Concrete Coatings	1.0	1.54 ft^3
Unqualified Coatings	1.0	10.5 ft^3
Margin for Coatings	1.0	2.1 ft^3
Latent Fiber	1.0	85 lb_m
Latent Particulate	1.0	482 lb_m
Foreign Material Allowance	1.0	655 ft^2

Conservatisms in the Debris Transport Analysis:

The overall impact of several substantial conservatisms for debris transport analysis is not quantified. Their impact, however, results in a conservative approach to debris transport. The conservatisms are described in the following list.

- DNC computed debris transport by considering the flowpath having the highest continuous velocity between the break location and the containment recirculation sump. This method adds a significant degree of conservatism to the overall debris transport results. It is conservative because a large fraction of the debris would realistically encounter smaller flow velocities, which could reduce the amount of debris actually reaching the sump strainers.

- All generated debris was assumed to be directed downward to the containment pool during the blowdown phase of a LOCA. As such, no credit was taken for capturing debris on gratings or other structures and equipment in upper containment. Although a significant fraction of captured debris could eventually be washed back down to the containment pool, assuming 100 percent of the debris directly enters the containment pool during blowdown is conservative with respect to the sump strainer design.

- 100 percent of the small fines of fibrous and particulate debris were assumed to transport to the suction strainers (including latent debris). Although small fines of fibrous and particulate material are expected to have a very high transport fraction, the assumption of complete transport for these types of debris is conservative.

- MPS3 performed the four CFD scenarios for large-break LOCA cases assuming a bounding minimum containment sump pool water level that corresponds to the start of recirculation for a small-break LOCA. For a large-break LOCA, the water level would actually be slightly increased due to additional contributions from sources such as the Safety Injection Tanks (SITs). Additionally, the water level at MPS3 continues to increase significantly after RSS pumps begin drawing suction from the sump. Ultimate water level attained in approximately 3 hours submerges the strainer by approximately 9 feet. This additional water would tend to reduce flow velocities in the containment pool and reduce the impact of turbulence from the break and containment sprays. Not accounting for the increased containment sump pool water level is conservative.

- Debris holdup was not credited in reactor cavity and inactive normal containment building sump. The potential for debris hold up in inactive containment pool volumes at MPS3 is small, and completely neglecting debris holdup in inactive pool volume calculations is conservative.

- MPS3 assumed that 90 percent of the large and small pieces of fibrous debris that settle in the containment pool would become fines that would transport to the sump strainers. This assumption was based upon guidance in Appendix III of the NRC SE. The assumption of 90 percent erosion for large and small pieces of settled fibrous debris adds considerable conservatism to the MPS3 transport analysis.

F. HEAD LOSS AND VORTEXING:

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

A schematic diagram of ECCS and CSS is included in Figure F-2 at the end of this section.

Minimum Strainer Submergence:

Minimum strainer submergence when RSS pumps begin taking suction from the strainer is nominally 8 inches for either a SBLOCA or a large break LOCA (LBLOCA). This is based on a minimum water level of 52 inches above the floor (elevation –24 feet 6 inches). The strainer is fully submerged and not vented prior to RSS pump start for all accident scenarios. The minimum water level of 52 inches (and thus the minimum submergence) is for a SBLOCA. Water levels for a LBLOCA are somewhat higher and thus submergence is somewhat higher for a LBLOCA. Maximum tested strainer head loss with a fully developed debris bed is 5.8 feet at the minimum saturation temperature expected at the start of recirculation (195°F). This value exceeds the minimum submergence of 8 inches. However, no flashing is expected to occur as described below. The minimum saturation temperature expected at the start of recirculation (195°F) is the saturation temperature corresponding to the minimum allowed containment pressure at the start of the accident. The clean strainer head loss is 0.382 feet or 4.6 inches at 100°F (and less at higher temperatures due to lower viscosity). A clean strainer exists at the start of recirculation and thus submergence will exceed head loss at the start of recirculation. The sump water is conservatively assumed to be saturated at the start of recirculation and the temperature of the sump water gradually drops during recirculation, the debris bed slowly builds up, and the containment water level rises during the first hours after RSS pump start as additional RWST water is sprayed into containment. The final containment water level (after the RWST is empty) results in a strainer submergence of approximately 9 feet, exceeding the maximum strainer head loss. This strainer submergence of approximately 9 feet occurs in a maximum of 3 hours (after the start of the accident). Based on large scale testing, the time to build a debris bed and reach the peak head loss is at least 24 hours after recirculation begins. This far exceeds the time to reach maximum submergence in containment. The result from large scale testing is conservative when compared to actual conditions in containment. This is because debris is added in the test tank adjacent to the strainer and there is no debris transport time in the test tank. Actual time for debris transport will likely increase the time required to form a debris bed and to realize peak debris bed head loss. Accumulation of buoyant debris on top of the strainer causing an air ingestion path is not considered credible due to the significant submergence of the strainer. Containment accident-induced pressure is not credited in evaluation of whether flashing would occur across the strainer surface.

Vortexing Evaluation:

Vortexing was evaluated in both the reduced-scale and large-scale test tanks. During all tests in both of those tanks, water level was set so that the test module submergence was less than or equal to the minimum strainer submergence in containment. In the reduced-scale test tank, a submergence of 8 inches was used to match the minimum design submergence of the strainer using a minimum containment sump water level of 4.33 feet. In the large scale test tank, a test was run with the clean strainer to evaluate vortexing. The water level was first set so that only the bottom 10 inches of the fins were submerged and twice the nominal flow was sent through the test tank and strainer. The submergence level was then set at 0 inches (the water level was raised to the top of the fins) again using twice the nominal flow rate. No hollow-core vortices (evidence of air ingestion) were observed at any of these submergence levels. No air bubbles were observed in the discharge piping during these vortexing tests. No hollow-core vortices were observed during any of the tests in either the reduced-scale or large-scale test tanks, confirming that vortexing for the new strainer is not a concern.

Air Ingestion:

Per Attachment V-1 to Appendix V of the SER and Regulatory Guide 1.82, the design of PWR recirculation sumps also needs to consider air evolution (release from solution) and air ingestion (i.e., due to vortex formation). Per Attachment V-1 to Appendix V of the SER, the inlet void fraction (total percentage of air and water vapor by volume) downstream of the screen should be limited to 3% to prevent cavitation problems with the ECCS/CS pumps. Per Regulatory Guide 1.82, the amount of air ingestion should be limited to 2% to prevent degraded performance of the ECCS/CS pumps. For the purpose of the evaluation of air ingestion, the 2% ingestion limit is conservatively applied to the total of the air and water vapor ingested by the pump (inlet void fraction) rather than the air alone. Therefore, immediately downstream of the sump screen, the void fraction must be less than or equal to 3%. Additionally, at the pump inlet, the void fraction must be less than or equal to 2%.

Air ingestion is examined analytically in the debris transport calculation to ensure that excessive air ingestion will not occur under the worst case conditions in containment. This evaluation demonstrates that total air ingestion will be low enough to prevent cavitation of the ECCS pumps.

The void fraction downstream of the screen is a function of the sump pool temperature and the head loss through the sump strainer and debris bed. As the strainer design must prevent flashing for the allowable head loss, the void fraction will only be due to air and water vapor evolved (released from solution) downstream of the strainer or air that is ingested into the strainer due to vortex formation. Vortex formation is addressed in testing as described above.

The void fraction due to air and water vapor evolved (released from solution) downstream of the strainer and at the pump suction is calculated by finding the maximum solubility of air in water upstream and downstream of the strainer and taking the difference as evolved air. Similarly, the maximum solubility of air at the pump suction is determined and compared to the maximum solubility downstream of the strainer with the difference being evolved air. The analytical evaluation (assuming no vortex formation) demonstrates that the void fraction downstream of the strainer is significantly less than 3% and the void fraction at the pump inlet is zero. Since there is no vortex formation and since there is no void formation at the pump inlet due to air ingestion, no adjustment to NPSH is necessary.

<u>Head Loss Testing</u>:

Chemical effects testing was not part of the head loss tests described below. Testing for chemical effects is detailed in Section O.

MPS3 contracted with AECL to determine required strainer surface area and fin pitch (spacing between fins) by testing. Initial strainer size was determined by AECL using the NUREG/CR-6224 correlation and tests were conducted with scaled plant debris loads to determine the final surface area and fin pitch for the strainer. Head Loss testing was conducted for MPS3 to determine the fin area and fin pitch for the replacement ECCS strainer under the worst-case debris loading conditions. The testing consisted of 11 reportable tests in a reduced-scale test tank and three tests in a large-scale test tank. Head loss testing was conducted in AECL test facilities at Chalk River, Ontario.

A set of testing procedures was developed to conduct the head loss tests. These procedures include debris preparation procedures, procedures to measure temperature, head loss and flow rate, debris introduction procedures and test termination procedures. A water jet from a pressure washer was used to separate fibers after small fiber batts were broken into smaller pieces using a leaf shredder. After the fiber was processed for reduced and large scale thin bed head loss tests, the particulate debris was introduced before the first batch of the fibrous debris. Then, the fiber debris was incrementally added into the test loop until the peak thin-bed head loss was observed. This method effectively tested multiple thicknesses of fibrous debris within a single test. For full debris load tests, the particulate was introduced proportionately with the fibrous debris. As part of the test module design, a baffle and skirt were arranged around the test module to reduce the disturbance caused by the turbulent flow eddies generated by the stirrer and the return flow. One of the purposes of the skirts was to simulate the presence of a debris bed from an adjacent fin or module. It limited any flow of debris out from under the test module to those areas that would be open in the final design. The presence of the skirts and baffle also helped minimize debris bed disturbance.

Reduced Scale Test Facility:

The reduced-scale test tank is a 90-inch diameter open plastic tank with a maximum fill height of 56 inches. The tank is equipped with flow, temperature, and differential pressure measuring instruments as well as heating elements capable of heating to a maximum temperature of 140ºF. The pump was capable of producing a flow rate between 1 and 120 gpm.

The reduced-scale test module consists of one central fin and two half fins to each side with adjustable pitches. The fins are constructed of perforated stainless steel with a perforation size of 1/16 inch and a vertically-oriented corrugated bend angle of 60 degrees. The half fins are similar to the central fin, but only have perforated material on the side facing the central fin. The other side of the half fins is solid. The fin dimensions are listed in the table below. The reduced-scale test module fin is of a similar size to one-half (one of two panels) of the MPS3 fins, with the back end of the fins in the test tank modeling the midpoint of the full MPS3 fins. The test module fins are approximately 6 inches shorter than the installed MPS3 fin. To account for the difference in fin heights between the test fin and the MPS3 installed fin, the tank water level was set to match the submerged water depth of the installed strainer (8 inches minimum). The fins used in the test tank were of the same construction/design as the fins for the installed MPS3 strainer.

Large Scale Test Facility:

The large-scale test tank is an open lined tank approximately 7.5 feet deep, 8 feet wide and 18 feet long. The tank is equipped with flow, temperature, and differential pressure measuring instruments as well as a heating and cooling system capable of controlling water temperature between 50ºF and 120ºF. The piping system is capable of producing flow rates from 300 to 3000 gpm.

The large-scale tank strainer test module is representative of the full-size MPS3 strainer, with ten half-size fins attached to a common header. The fin dimensions are listed in the table below. The test module fins are the same width as a half fin in the installed MPS3 strainer. The fin height and submerged depth match the strainer installed at MPS3. The height of the test module off the tank floor was 27 inches in the large-scale test tank. This is greater than the MPS3 strainer, which is approximately 7 inches off the containment floor. Based on continuous stirring with two stirrers in the test tank, and periodic sweeping of the tank to re-suspend settled debris, this difference in height above the containment floor is not expected to have a significant impact on the results of the full debris load test. Baffles with shelves were placed in the test tank to prevent debris from building up around and below the test module where this wouldn't be possible in containment. This difference in height will not have any effect on the thin bed test debris bed formation or head loss due to the continuous stirring and because debris that settles is going to settle due to low velocity independent of the height of the fins. To the extent practicable, all of the debris in the test tank was maintained in suspension using the stirrers.

Table F-1: Module Dimensions

	Fin Dimensions Length x Height (inches)	Module Surface Area (ft^2)	Submerged Depth (inches)	Fin Pitch (inches)	Support Height (inches)
Reduced Scale Test	35 x 30	52.5	6	8	11
Large Scale Test	33.25 x 36.38	296	8	8	27
MPS3 Installed Strainer	67 x 36	296	8	8	7

Test Description:

AECL used the reduced-scale head loss test loop to perform a series of tests to determine the thin bed thickness, and optimize the total surface area and fin pitch for normal debris. Based on the reduced-scale head loss test loop results, the final strainer module design was tested using the large-scale head loss test facility for thin bed head loss tests and full debris load tests.

Based on analytical head loss predictions, a thin-bed will produce the worst head loss. Based on AECL experience with a corrugated finned strainer designed for French PWRs, the worst case head loss occurred with a thin-bed of fiber approximately ¼-inch thick.

To determine the worst-case thin-bed thickness and the optimum strainer surface area, the full particulate load was added to the test tank. This was followed by fibrous debris additions in increments calculated to provide a 1/16-inch thickness on the test module. Head loss was allowed to stabilize after each fiber addition. This was continued until the total bed thickness was one or two increments beyond the thin-bed thickness (seen as a reduction in head loss increase per fiber addition). Measured head loss was recorded and plotted versus the fiber quantity and compared with the analytical correlation results (NUREG/CR-6224) and the head loss acceptance criteria. The final two reduced-scale tests used to determine the total surface area of the strainer (thin-bed tests) had durations of more than 48 hours to allow appropriate head loss stabilization.

To determine the optimum fin pitch, head loss testing was conducted with the full debris load. Baffles were installed on the test module to prevent debris between the fins from being pushed out either under the header or under the side. Debris for the final reduced-scale full debris load tests was added in 4 increments over 35 minutes.

Final reduced-scale tests used to determine the total strainer area and fin pitch of the strainer were conducted at a tank water temperature of 104ºF and a flow rate of 101 gpm. The water temperature in the test tank was lower than the sump pool initial temperature. Thus, the test tank flow rate is the same as the sump pool flow rate adjusted for strainer area scaling (due to size difference between the test module and the strainer installed in containment).

Total installed strainer surface area is 5041 ft^2. This exceeds the total tested surface area (scaled) of 4290 ft^2 by more than the 655 ft^2 allocated for tags and stickers, and is thus conservative. A larger surface area was installed in order to standardize the strainer module size and still envelope the surface area that the analyses indicated was needed. Using the maximum water flow through the strainer of 8220 gpm, dividing flowrate by surface area gives the strainer face velocity in containment as 0.0036 ft/sec. For the thin-bed testing in the reduced scale test tank, the test module surface area is 52.5 ft^2 and the test module flowrate is 101 gpm. Dividing flowrate by surface area gives a test module velocity of 0.0043 ft/sec, which is slightly higher than the flowrate in containment and thus conservative since the higher flowrate in the test tank will allow for less debris settling. Similarly, for the large scale test tank, the module surface area is 296 ft^2 and the flowrate is 567 gpm. The resulting bulk velocity in the large-scale tank is 0.0043 ft/sec.

Total circumscribed area for the installed strainer is approximately 1110 ft^2. This is the surface area seen by approaching debris when each of the strainer modules is fully encapsulated in debris. The resulting containment velocity is the high end of the bulk velocity at the strainer and is calculated by dividing the flowrate by the circumscribed area. The resulting maximum bulk water velocity in containment is 0.0165 ft/sec. The corresponding velocity in the reduced-scale test tank using the circumscribed area of the test module (approximately 7.2 ft^2) is 0.031 ft/sec. Similarly, for the large-scale test tank, the circumscribed surface area is approximately 50.7 ft^2 and the corresponding bulk velocity is 0.025 ft/sec.

Settling of debris in containment (especially particulate) is inevitable due to the very low water velocities and the many surfaces available for settling. This settling will reduce the debris able to arrive at the strainer and contribute to head loss. To ensure that a conservative amount of debris arrived at the strainer test module, test tank water was continuously stirred in both reduced-scale and large scale test tanks. Additionally, the large scale test tank was periodically swept to re-suspend settled debris. For the thin-bed test due to the slightly higher test tank bulk velocities, this stirring likely prevented settling of debris in the test tank that would actually settle in containment and thus the amount of debris on the test module strainer (and thus the required strainer area) is likely conservatively high. For the full-debris load tests, the maximum bulk velocity in the test tank exceeds the maximum bulk velocity in containment with a circumscribed strainer and thus is conservative since more settling is likely to occur in the slower-moving water in containment. The continuous stirring ensured that the head loss from the large scale tests likely exceeds what would occur in containment. The head loss from the full debris load tests was approximately ¼ of the head loss for the thin bed tests in both the reduced-scale and large-scale tests due to the large fiber load in the full debris load tests. Visual observation of debris settling in both the reduced scale and large scale test tanks showed that some debris settled outside the baffled fins, but not a significant amount.

Test termination criteria for the reduced-scale testing was a change of less than 5% or 0.01 psi, whichever is greater, and exhibiting no general steadily increasing trend in pressure, within 1.5 hours. Note that a tank turnover (defined as the time equal to the test tank water volume divided by the flow rate) for MPS3 reduced-scale testing was typically 13 minutes.

Test termination criteria for the large-scale testing was a change of less than 5% or 0.01 psi, whichever is greater, and exhibiting no general steadily increasing trend in pressure, within nine tank turnovers. A tank turnover is defined as the time equal to the test tank water volume divided by the flow rate. A tank turnover for MPS3 large-scale testing was typically 10 minutes.

<u>Debris Preparation</u>:

Fibrous Debris was prepared as follows:

- cut the fiber batts into pieces of approximately 6 in. (0.15 m) by 6 in. (0.15 m),
- broke the pieces into smaller pieces using the leaf shredder,
- measured the mass of fiber for each specific addition,
- combined the fiber addition with water,
- agitated the mixture for 2 to 5 min with a water jet from a pressure washer to separate the fibers, and
- confirmed that the degree of fiber separation met expectations and was consistent with other batches used.

Particulate debris included Microtherm and surrogates for both coatings and latent particulate and was prepared as follows:

- measured the mass of particulate for each specific addition,
- photographed a typical particulate addition during the test program, and
- combined the particulate addition with water.

Ability of the Design to Accommodate the Maximum Volume of Debris:

The analytical transport calculation included the maximum quantities of debris able to transport to the strainer. Head loss testing was conducted using this full debris load to determine fin spacing so that all of the debris was accommodated on the strainer and the head loss limits were not exceeded. Head loss testing was conducted with the full debris load in both the reduced-scale and large scale test tanks to determine the amount of strainer encapsulation and the resulting head loss. The debris composition for these tests was based on the break with the highest debris load.

In the reduced-scale test tank, the full particulate and fiber debris loads were added in increments near the start of each test. For full debris load testing, the front baffle on the test module was not utilized as the debris bed was allowed to encapsulate the test section both in front of the fins and on top of the fins below the water surface.

In the large-scale test tank, the full debris load was added at the start of the test in 25% increments. After the final debris addition, the test was continued until the pressure drop stabilized. The bottom of the test tank upstream and on both sides of the test module and the top of the cover plate were periodically brushed to re-suspend fiber and/or particulate in order to reduce the quantity of debris that settled upstream and beside the test module. With all the debris on the strainer, encapsulation of the strainer occurred with approximately 2-3 inches of debris above the strainer fins in both the large-scale and reduced-scale tests. In no test did this encapsulation exceed the minimum submergence of the strainer and so does not lead to air ingestion. The head loss for these full-debris load tests was well within the acceptance criteria and significantly less than the thin-bed head loss results (see Table F-3 below).

Ability of the Design to Accommodate Thin-Bed:

Head loss testing has demonstrated the ability of the strainer to accommodate the formation of a thin-bed of debris. The debris added for the thin-bed tests conservatively used the minimum amount of fiber necessary for thin-bed formation combined with the entire LBLOCA particulate debris load.

In the reduced-scale test tank, baffles were positioned across the back and front of the fins to prevent water turbulence from either the tank return line or the stirrer from disturbing the debris bed. The full particulate debris load was added at the start of the test and then additions of fiber were made in 1/16-in. (1.6-mm) theoretical bed thickness increments until the debris bed thickness was two 1/16-in. (1.6-mm) increments beyond the thin bed thickness. Note that the theoretical bed thickness is defined as the uncompressed fiber volume divided by the test module surface area. The first fiber addition was made approximately 30 min after the particulate addition. The second fiber addition was made approximately 1.5 h after the first addition. Subsequent fiber additions were only made once the pressure increase resulting from previous additions had stabilized. The minimum time between additions was 1.5 h.

In the large-scale test tank, the full particulate debris load was added at the start of the test and then additions of fiber were made in 1/16 inch theoretical bed thickness increments until the total bed thickness was 3/8 inch, two increments beyond the thin bed thickness of 0.25 inch as determined from reduced-scale tests. Note that the theoretical bed thickness is defined as the uncompressed fiber volume divided by the test module surface area. The first fiber addition (1/16 inch) was made 0.5 h (approximately three tank turnovers) after the addition of the particulate. The second fiber addition (an additional 1/16 inch) was made 1.5 h (approximately nine tank turnovers) after the first addition. Subsequent fiber additions were only made once the pressure increase resulting from previous additions had stabilized, defined as changing by less than 5% or 0.01 psi, whichever was greater, and exhibiting no general steadily increasing trend in pressure within 1.5 h (approximately nine turnovers).

Debris Surrogates:

Debris surrogates used for testing are listed in the table below. Scaled quantities of debris for the head loss testing are determined by dividing the amount of debris expected to transport to the strainer (based on the analytical transport calculation) by the ratio of final designed strainer surface area (4290 ft^2) to test module surface area (52.5 ft^2 for the reduced scale test).

Table F-2: MPS3 Testing Debris

MPS3 Debris	Surrogate for Testing
Transco Fiberglass	Transco Thermal Wrap
NUKON™	Transco Thermal Wrap
Microtherm	Microtherm
Latent Fiber (lb_m)	Transco Thermal Wrap
Qualified Coatings (ft^3)	325 Mesh Walnut Shell
Unqualified Coatings (ft^3)	325 Mesh Walnut Shell
Latent Particulate (lb_m)	325 Mesh Walnut Shell

Use of Transco Thermal Wrap as a surrogate debris for NUKON™ fiberglass is reasonable since the material density and the fiber diameter is similar for Transco Thermal Wrap and NUKON™. Thus, the materials' head loss behaviors are also similar. Additionally, the amount of Transco fiberglass postulated in the debris bed far exceeds the amount of NUKON™ fiberglass so any small difference in their properties is insignificant to their behavior in the test facility.

Transco Thermal Wrap is identical to Transco fiberglass installed at MPS3 so no surrogate is required.

Microtherm similar to that installed at MPS3 is available and was used in the head loss testing so no surrogate is required.

Coatings in the MPS3 containment consist largely of epoxy, inorganic zinc, and alkyds. Of these coatings, much is epoxy and the density of epoxy (94 lb_m/ft^3) is lowest of the three. Thus, the epoxy coating is most likely to remain suspended in the containment sump pool and be deposited on the strainer surface. Conservatively, all of the coatings are assumed to be epoxy. Ideally, epoxy coating would be used in the test tank to avoid the use of a surrogate. However, no effective method exists to produce the approximately 10 μm size for the coating pieces. All of the coating is analytically assumed to fail as 10 μm particulate consistent with the NRC SE to produce the worst-case debris bed head loss.

Walnut shell was chosen as a conservative surrogate for coatings debris. The density of walnut shells is approximately 75-87 lb_m/ft^3, which makes it able to be suspended in water longer than epoxy, and is thus conservative for testing. Testing of the ground walnut shell used in the head loss tests has shown that it does not coagulate in water in the absence of flocculating agents and its volume change in water is small (average of 2.3%).

Walnut shell is available with a mean size of approximately 23 μm and a size range of 5 μm to approximately 60 μm. This is a reasonably close match to the expected size of epoxy coating chips assumed in the analytical transport calculation and provides a sufficiently conservative head loss.

AECL used walnut shell flour to simulate all plant coatings and latent debris particulate debris. With regard to both qualified and unqualified coatings debris, AECL's testing objective was to accumulate the scaled-down bounding volumes of particulate on the test strainer with particles approximating the nominal GR-recommended 10 μm diameter particle size. AECL initially attempted to test with silicone carbide particulate but encountered such extensive settling within the test tank and deposition even within the circulation piping that the test objective of accumulating the majority of the particulate on the strainers could not be reasonably achieved. The material density of the silicone carbide was 196-lb_m/ft^3 whereas the density of the primary coating debris (epoxy) is 94-lb_m/ ft^3. The silicone carbide was selected based in its size distribution, which basically reflected the GR 10 μm recommendation. Subsequently, AECL used the walnut shell flour with a density of approximately 81-lbm/ft^3 to simulate the coatings particulate. Most of the walnut shell flour accumulated on the test strainer, rather than settling or depositing, thereby resolving the non-prototypical settling encountered with the silicone carbide.

The AECL analysis of the walnut particle size distribution determined that the average size was about 23 μm, and (from a specific surface area consideration based on spherical particle shape assumption) the effective particle size was about 32 μm. This means that the walnut flour particles were a factor of about 3.2 larger than the GR recommendation, which translates to a factor of 10 decrease for head loss impact. Note that at the very low approach velocities associated with the MPS3 replacement strainer, the head loss is approximately linear with the square of the specific surface area. The specific surface area for the walnut flour size distribution, assuming spherical particles, is about 57,000 ft^2/ft^3, as compared to 183,000 ft^2/ft^3 for the SE-assumed particulate. Therefore, if only the walnut flour hydraulic characteristics are considered, a conclusion could be drawn that walnut flour may not be a good surrogate material to meet GR and SE coatings requirements.

DNC concludes that walnut shell flour simulates MPS3 coating particulate and latent particulate in an acceptable manner. Equivalent head loss behavior overcomes any particle size disparities. This conclusion considers the transport, filtration and head loss properties of the walnut shell flour as a surrogate for coatings and latent particulate. The basis for concluding equivalent head loss behavior has also been discussed in the Millstone Power Station Unit 2 GL 2004-02 Response Audit Report (ADAMS Accession No. ML072290550).

<u>Head Loss Testing Results and Strainer Design Maximum Head Loss:</u>

The final qualification of the replacement strainer was based on one large-scale thin-bed test and one full load head loss test. Table F-3 below lists the results and the comparison with the relevant reduced-scale head loss test results.

Table F-3: Large-Scale Head Loss Tests Results

Debris Loading	Test Type & ID	Head Loss (psi)
Thin Bed	Reduced Scale Test M3-2	5.1
	Reduced Scale Test M3-16	3.6
	Large Scale Test M3L-2	7.7 (peak) 4.7 (stabilized)
Full Load	Reduced Scale Test M3-4	1.3
	Large Scale Test M3L-3	1.13

The maximum peak measured debris head loss is 7.7 psi at 104°F. The maximum stabilized debris head loss is 4.7 psi at 104°F. The acceptance criteria for debris head loss is 6.49 feet of water at saturated conditions. This value was converted to psi and scaled to the test tank temperature of 104ºF to arrive at acceptance criteria of 5.3 psi at 104°F. AECL used a linear extrapolation scheme to determine the viscosity-corrected head loss based on the maximum measured debris bed head loss. Testing with the full debris load in the reduced-scale test tank exhibited some evidence of debris bed cracking and repair (boreholes). This was seen in periodic drops and recovery in the differential pressure across the debris bed. However, no tests were terminated prior to repair of these debris bed cracks as evidenced by the subsequent recovery in differential pressure. No evidence of this phenomena occurred in the thin-bed tests in either the reduced scale or large scale test tanks. Thus, scaling of the test tank results using viscosity is not affected by formation of boreholes.

Not considering potential chemical effects, AECL used linear extrapolation (pressure drop proportional to the viscosity) to predict the maximum debris bed head loss acceptable at the test tank temperature of 104°F. Because the flow rate is very low close to the strainer, and the flow regime is estimated to be laminar, the friction loss is proportional to the viscosity. Therefore, linear extrapolation is considered appropriate.

The design maximum strainer head loss is 6.49 feet of water at saturated conditions. This is based on the minimum margin to suction line flashing for the RSS pumps at MPS3. The RSS pumps are the only pumps to take suction through the sump strainer. The NPSH margin for the RSS pumps exceeds the margin to suction line flashing. The maximum head loss allowed across the strainer by structural analysis is 10 psi (equivalent to greater than 20 feet at 100°F), which far exceeds the maximum allowed debris bed head loss.

The peaks in head loss during the thin-bed test in the large scale test tank occurred due to release of air from solution when the head loss across the debris bed lowered the pressure in the debris bed below the static pressure of water on top of the debris bed. These peaks in head loss seen in the test tank will not occur in the MPS3 containment since the static head on the strainer will be at a minimum when the RSS pumps start (and debris begins to be drawn towards the strainer). RSS pump start occurs when approximately 1/2 of the RWST (500,000 gallons) has been injected into containment. The static head will then rise as more RWST water is spilled into containment due to the continuing action of the QSS pumps. The remaining RWST water (approximately 500,000 gallons) is then injected into containment while the RSS pumps are running. The QSS pumps empty the RWST within a maximum of 3 hours from the start of the accident. The RSS pumps start as soon as approximately 37 minutes after the start of the accident. Based on the test data and supplemental investigative activities of the air-bubble behavior in the debris bed and strainer fins, the static head in containment will exceed the debris bed head loss throughout the debris bed formation. When the RWST is completely emptied into containment, the maximum water height is approximately 13 feet above the containment floor, which is approximately 9 feet above the top of the strainer fins. The allowable strainer debris bed head loss (scaled for changes in viscosity which are proportional to head loss and allowing for a clean strainer head loss of 0.382 feet) is 5.3 psi at the large scale test tank temperature of 104°F. Formation of the debris bed is shown in the large scale tests to require at least 24 hours far exceeding the 3 hour time to empty the RWST and establish maximum strainer submergence. Because of the significant static water head on the strainer prior to debris bed formation, air bubbles are unlikely to form in a debris bed in containment, and the resultant head loss peaks seen in the large-scale test tank will not be seen in containment. Since worst-case debris bed formation occurs well after the final containment water level peak strainer head loss, the results are acceptable.

Clean Strainer Head Loss:

Clean strainer head loss was determined using analytical calculations. Pressure loss is comprised of five components: loss through the debris, internal losses in the fins, merging losses of the flow from the fins joining with the collection channel flow, friction and shock losses in the collection channel. Debris pressure drop is determined experimentally, while internal losses are calculated based on standard calculation techniques for flow in pipes and ducts. The calculations were conservatively performed assuming a temperature of 100°F. The pressure losses in the strainer are presented for the case of flow entering the strainer uniformly through all of the fins, because this is the most realistic situation during strainer operation and it gives an upper bound of the internal pressure loss. With totally clean fins, the flow in the strainer is non-uniform, whereby the strainer modules located directly above the sump pit are predicted to have about 60% more flow per module than the nominal value, and the predicted internal loss is roughly 1% of the allowable head loss at the maximum temperature (~0.08 feet vs. ~6.5 feet). Once even a small layer of debris builds up, the flow entering the strainer modules will quickly equalize. As more flow enters the strainer from the modules farther from the sump, the internal losses rise, reaching 0.38 feet once flow has fully equalized. This is still only about 6% of the allowable head loss due to debris at the maximum temperature, and will not govern the overall flow distribution. As the sump cools, debris head loss will increase further, making the internal losses even less significant.

The analytical clean strainer head loss is 0.382 feet of water at 100°F. The strainer system consists of a total of 17 side-by-side strainer modules, 9 above the floor area and 8 above the sump, as shown in Figure F-1.

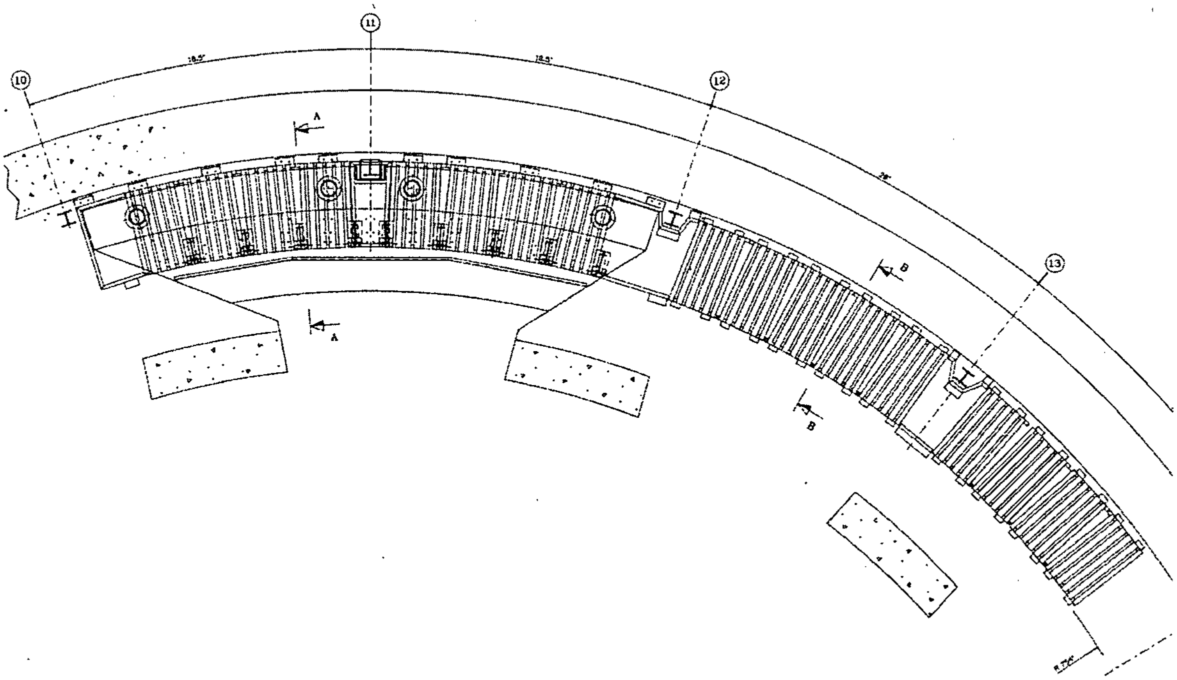
The major pressure losses in the strainer system are summarized in Table F-4. The pressure losses in Streams 2 and 3 (over the sump pit) are small because the sump pit represents a large flow area that offers little flow resistance. The pressure loss in Stream 1 (strainer area extending beyond the sump pit) is dominated by the shock loss at the inlet to the sump. The uniform flow in all fins is the bounding case for clean strainer head loss.

An analysis was performed to check the effect of non-uniform flow into the pump inlets on the overall pressure loss. The flow into the pumps was varied by 20% at either end to simulate a mal-distribution of flow from the 1st pump inlet to the 4th pump inlet (i.e., flow rate into the pumps was set at 2467, 2261, 1849 and 1643 gpm for pump inlets 1 to 4, respectively). It was found that the effect of this variation on the overall pressure loss of the strainer train was less than 0.6%. The effect is small because most of the pressure losses occur in the side train before the flow enters the sump area.

Table F-4: Clean Strainer Head Loss

Component	Description of Pressure Losses for Uniform Flows in all Fins	Pressure Loss (Pa)
ΔP Stream1	Friction and Shock Losses in Stream 1	1018
ΔP Stream2	Friction and Shock Losses in Stream 2	12.8
ΔP Stream3	Friction and Shock Losses in Stream 3	20.2
ΔP Overall (no fin losses)	Overall losses excluding fin losses	1051 0.354 ft water
ΔP Fin Losses	Friction and Shock Losses in Clean Strainer Fins	83.7
ΔP Overall (with fin losses)	Overall losses including fin losses	1134 0.382 ft water

Figure F-1: MPS3 Strainer Layout



Near-Field Effect:

The Near-Field effect is debris settling upstream of the strainer in a head-loss test flume or tank due to low flow velocities. Intact pieces of low-density fiberglass (35% of total low-density fiberglass generated) and 10% of the large and small pieces (those that didn't erode) were credited with not being on the strainer surface in the analytical debris transport calculation as discussed above. No other settling of debris was credited in the debris transport calculation since all other debris is transported to the strainer and is assumed deposited on the strainer fins. The debris transport calculation results determined the amounts and types of debris used in the head-loss test tank. That testing was used as the basis for the design of the MPS3 strainer. Because intact pieces of low-density fiberglass and un-eroded small and large pieces of fibrous debris were analytically shown to be unable to lift onto the strainer fins, they were not added to the test tank during head-loss testing.

Tests were conducted to size the strainer for the postulated debris loads using a reduced scale test facility described above. The design of the tank and associated supply and return piping minimizes debris settling and maximizes the amount of debris which is entrained in the water and deposited on the strainer surface. Large scale tests confirmed that the strainer size determined in the reduced scale facility is adequate. Stirring was done in both the reduced and the large scale test facilities to suspend as much debris as possible and deposit it on the strainer surface. Despite the stirring, some of the debris settled. Since the velocities in the test tank were representative of containment and because of the stirring which resulted in a conservatively low amount of settling compared to what is likely to occur in containment, no excessive settling of debris occurred during head loss testing for MPS3.

Significant Margins and Conservatisms in Head Loss and Vortexing Analyses:

Reduced-scale test tank was used to determine debris strainer design size and fin pitch by measuring debris head loss. The small diameter of the tank and the constant stirring ensured that a minimal amount of the debris settled on the floor of the tank thus maximizing the amount of debris and subsequent head loss across the test fins. Settling of small debris in containment is expected to be significant, especially in areas remote from the strainer.

The maximum head loss is dependent on formation of a thin-bed on the strainer surface. Formation of a thin-bed is dependent on a small quantity of fiber mixing with all of the particulate on the strainer. Additional fiber, beyond the minimum quantity required for the thin-bed tends to produce lower head losses. Thin-bed formation conservatively used the minimum quantity of fiber necessary to form a thin-bed in combination with the maximum LBLOCA particulate load. This conservative combination is very unlikely to occur at the strainer for either a SBLOCA or a LBLOCA.

Vortexing analysis and testing showed no vortexing with a partially submerged strainer as described above and for a strainer that has zero submergence (water level at the top of the strainer). The installed strainer at MPS3 has a nominal 8 inches of submergence at the beginning of recirculation and this value increases as the RWST continues to be sprayed into containment. Only about half of the RWST has been put into containment when the RSS pumps start and begin taking suction from the containment sump.

Maximum head loss is calculated at the minimum containment sump water level. The minimum water level only occurs at the beginning of recirculation and water level increases as additional RWST water is sprayed into containment. The maximum head loss will not be established until significantly after RSS pump start and, based on head loss testing, will not occur until significantly after the approximately 3 hours required for all of the RWST water to be pumped into containment, submerging the strainer by approximately 9 feet.

Head loss testing involved adding all of the particulate to the test tank prior to the addition of any fiber and then adding fiber in increments to gradually build a thin-bed on the strainer. An actual break is much more likely to mix all of the available fiber and particulate together in the sump pool so that they arrive at the screen together and thus are unlikely to form a thin-bed since there is likely to be more fiber in the mix than is necessary for thin bed formation. This will lead to lower head losses.

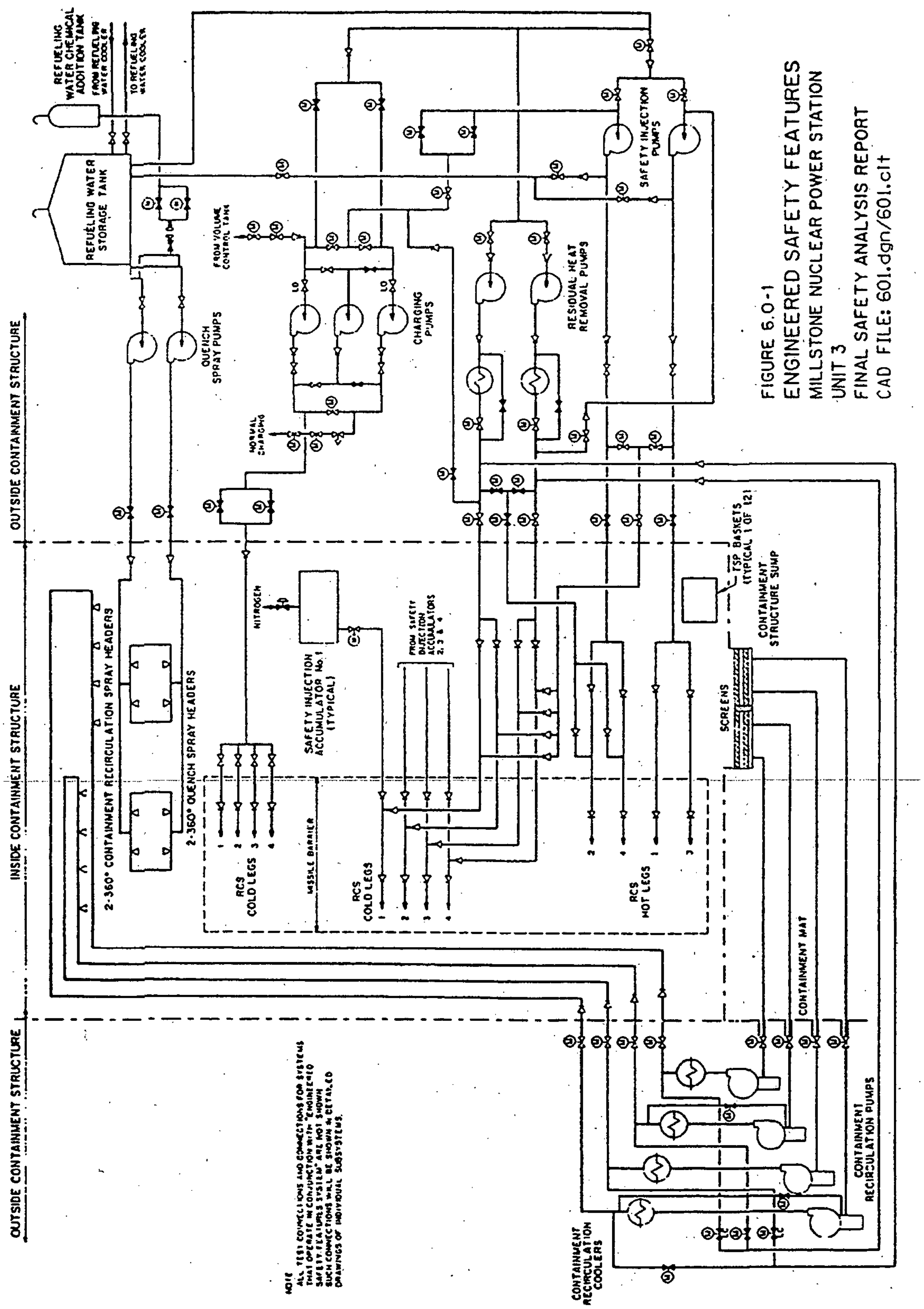


Figure F-2: Schematic Diagram of the Emergency Core Cooling System (ECCS) and Containment Spray Systems (CSS)

G. NET POSITIVE SUCTION HEAD (NPSH):

System Response for Large and Small Break LOCAs and Pump Operation Status:

The MPS3 ECCS design includes several sets of pumps that reduce containment temperature and pressure and remove core heat following an accident. Following a design basis LOCA, RCS pressure will drop resulting in a safety injection signal (SIS) and containment pressure will rise resulting in a containment depressurization actuation (CDA) signal. Upon receipt of the SIS, the charging pumps, intermediate high head SI pumps and low head safety injection (RHS) pumps are started to inject water into the RCS from the RWST. Upon receipt of the CDA signal, the QSS pumps also 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-low level point, (approximately half full), the transfer to the recirculation mode is initiated. On this RWST level signal, the RSS pumps automatically start (and begin drawing water from the containment sump) and the RHS pumps automatically stop. The SI and charging pumps are manually realigned to take suction from the discharge of one of the two RSS pumps on each train to continue core heat removal. These pumps remain aligned to the spray headers and excess RSS pump flow not used by the ECCS pumps is directed to the spray headers. The other RSS pump on each train continues to discharge to its spray header to continue lowering containment temperature and pressure. The QSS pumps continue to take suction from the RWST and discharge to spray headers until they stop automatically on a RWST level signal indicating that the RWST is empty. Recirculated containment water is provided to each RSS pump through a dedicated inlet line from the containment emergency sump. Each RSS pump discharges to a dedicated RSS heat exchanger that is cooled by service water from Long Island Sound.

After approximately 9 hours, cold leg recirculation is terminated by operator action to initiate two path circulation. In this mode, the containment recirculation pumps continue delivery from the sump to:

a. the two charging pumps which continue to deliver to the reactor through their cold leg connection, or the cold legs via the low pressure injection lines (using RSS pumps), if the two charging pumps are lost due to a passive failure; and,

b. the SI pumps which deliver to the reactor through their hot leg connections.

RSS Pump Flow Rates:

The RSS pumps are the only pumps to take suction from the containment sump and they start when the low-low level signal is reached in the RWST (when the RWST is about half full). Maximum RSS pump flow in any design basis case is nominally 8220 gpm which is the maximum design flowrate through the strainer.

The hydraulic calculation that determines the RSS pump flow rates uses an industry-standard hydraulic program to model the piping, valves, and pumps in the RSS system. Various system alignments were modeled as well as various single failure scenarios to ensure that system analysis covered all possible scenarios. Orifices are in place downstream of each RSS pump to limit flow from each pump to 3000 gpm +5% uncertainty (3150 gpm). These orifices are installed to limit pump flow and so prevent RSS pump suction line flashing.

Pipe friction is determined using standard hydraulic formulas, roughness of commercial steel pipe, and an assumption of fully turbulent flow. Other flow losses are accounted for by using resistance coefficients of components such as orifices, valves, elbows, and tees per component design drawings or standard hydraulic assumptions similar to those found in the Crane Technical Paper 410 (Flow of Fluids through Valves, Fittings, and Pipe).

During original plant construction, a concern was identified for cavitation of the RSS pumps on startup due to inadequate NPSH due to high flows on pump startup. Testing accomplished in December 1980 operated an RSS pump at 5000 gpm with the suction valve throttled down to produce a significant loss of discharge head (severe cavitation) for five minutes. During this run, no abnormal sounds or vibration were observed. The test report concluded that the loss of suction test more than adequately demonstrated satisfactory pump performance at severe loss of suction conditions. The conditions described in the test report bound conditions which may be encountered by the RSS pump on startup post-LOCA. Startup flows post-LOCA could be as high as 3000 gpm per pump until the discharge header is full (approximately 1 minute) when flows will drop to a steady state maximum of 2450 gpm per pump. Pump performance will not be affected by short-term flows above 2450 gpm.

Required NPSH Values:

The required NPSH specification of the pumps is presented in the form of graphs from the pump manufacturer. The required NPSH values for the RSS pumps are based on a 1% head drop determined from pump-specific test data. This is more conservative than the standard 3% head drop criterion. A hot fluid correction factor was not used to scale the value of required NPSH determined at room temperature to a reduced value based upon the applicable post-accident fluid temperature in calculating NPSH margin. Neglecting the hot fluid correction factor is conservative.

Single Failure Assumptions:

The RSS pumps are the only pumps taking suction through the sump strainer. Maximum flow through the strainer assumes all four RSS pumps running undegraded in the design basis alignment which produces the most flow. The RSS pumps supply water to the spray headers and to the Charging (CHS) and Safety Injection (SIH) pumps during recirculation. The RHS (low head) pumps stop on an RWST level signal. Their failure to stop will not adversely affect the flowrate through the strainer since they do not take suction through the strainer.

The following single failure scenarios are relevant to pump operation and sump performance.

- One train (2 RSS pumps, 1 SI pump, 1 CHS pump, 1 RHS pump) could fail. Core cooling is provided by the redundant train.
- One RSS pump could fail. This is bounded by the loss of one train.
- One RHS pump could fail to stop on RWST level but the RHS pumps do not draw suction from the containment sump. Failure of an RHS pump to stop would deplete the RWST faster, but since all the water is directed to the containment via the RCS there would be no impact on the containment water level assumptions or on the strainer flow rates.
- A limited passive failure is postulated to occur 24 hours after accident initiation. The limiting passive failure could result in the loss of one SIH pump and all CHS pumps which would leave one RSS pump providing both cold leg and hot leg injection and three RSS pumps providing spray. This alignment results in a maximum flow through the strainer of approximately 8263 gpm. This alignment occurs at least 24 hours after accident initiation when water level in containment is approximately 9 feet above the top of the strainer and the sump water is significantly subcooled. Because of these factors, NPSH available to the RSS pumps is significantly increased above the minimum required and the head loss caused by the additional 43 gpm flow above the strainer design maximum flow of 8220 gpm does not hinder operation of the ECCS pumps.

Sump Water Temperature:

Assuming saturated conditions in containment is conservative for NPSH margin for the ECCS pumps since it sets water vapor pressure equal to containment atmospheric pressure. Minimum sump temperature produces the highest head loss across a strainer debris bed due to higher water viscosity and density. NPSH margin for the ECCS pumps is smallest at the beginning of the accident when the water in containment is saturated and no accident-induced overpressure is assumed. Since MPS3 does not credit containment accident-induced overpressure for NPSH of the ECCS pumps, use of the saturation temperature for the lowest possible initial pressure in containment is conservative for determining initial NPSH margin and is appropriate for determining the limiting head loss. As time passes after the initial break, cooling of the containment sump water provides additional NPSH margin (due to decreasing vapor pressure of water while atmospheric pressure remains constant). This decreasing vapor pressure more than offsets increases in head loss across the debris bed due to increasing sump water viscosity and increases in piping friction losses upstream of the ECCS pumps. This conservatism is not quantified and is not credited in the design.

The saturation temperature of the containment sump pool water at the lowest containment pressure that could exist at the start of the accident is 195°F. This temperature is used for determining the allowable debris bed head loss in strainer testing.

Minimum Containment Water Level:

Minimum Water level for a SBLOCA is 4.33 feet. This water level was used for the design and testing of the strainer.

Assumptions that are used in the minimum water level calculation to determine a conservatively low minimum water level include the following. The minimum sump water level was determined assuming that no water was spilled from safety injection and some injected water is assumed available to maintain the mass in the RCS. Except for containment sprayed water, no delay times for water falling to the containment floor are assumed since it is considered to be insignificant due to the extensive delayed RSS pump start near the RWST Low-Low level signal. Condensed water from the containment atmosphere is assumed to fall uniformly throughout the entire containment cross-sectional area. Mass lost in condensate film on heat sink surfaces is assumed equivalent to a 0.016 inch thick film on over 900,000 ft^2 of surface area. Filling of discharge piping, coolers, and spray headers is included in the calculation of recirculation spray flow rates and determination of minimum water level. These assumptions result in the minimum possible sump water level for at RSS pump start.

Determination of minimum water level at MPS3 included determining volume displaced by permanent structures on the lowest elevation of containment as well as determining the volume of water required to fill the containment sump and suction piping for the RSS pumps. Plant drawings and standard geometric calculations were used to determine volume occupied by internal structures. Internal structures included the reactor cavity and interior concrete supports and cubicles. Volume occupied by large equipment such as the pressurizer relief tank, safety injection accumulators, and containment air recirculation cooler tube banks was neglected thus adding conservatism to the minimum water level calculation.

Pool volume for the minimum water level is provided only by the RWST, which exhausts a minimum of 597,593 gallons.

At RSS pump start, minimum NPSH margin is in excess of 19 feet. Minimum margin to suction line flashing is 5.2 feet assuming a flow rate of 3000 gpm per suction line. If flashing occurs in the inlet lines, flow to the pump impeller will be prevented due to the suction line flashing. Severe loss of NSPH margin will occur if significant suction line flashing occurs in the RSS pump inlet lines.

This value of suction line flashing margin (5.2 feet) is overly conservative since 3000 gpm is not a steady state flowrate for any RSS pump in any alignment. To determine the actual margin to suction line flashing, a more reasonable, yet still conservative flow rate of 2450 gpm was used for each RSS pump. The resultant reduction in head loss due to the lower flow rate raises the margin to suction line flashing. The resulting suction line flashing margin is 6.49 feet which is used in strainer design.

Each RSS pump has a minimum of 0.6 feet NPSH margin at RSS pump start using maximum debris bed head loss of 5.8 feet and maximum allowable head loss of 6.49 feet at saturated conditions.

H. COATINGS EVALUATION:

Containment Coating Systems:

Steel surface coating systems include:

- Keeler & Long White Epoxy Primer No. 6548/7107 and may include a finish coat of Keeler & Long Epoxy Enamel E-1 or D-1 Series.

Concrete walls and ceilings in containment have an original coating of:

- Keeler & Long Epoxy Primer No. 6548 (seal coat) and 6548S (surfacer) and Keeler & Long E-1 epoxy enamel (finish coat).

Concrete floors are coated with any of five coating systems, which are:

- Keeler & Long Epoxy Primer No. 6548 (seal coat) with a finish coat of Keeler & Long D-1 Series Epoxy Hi-Build Enamel,

- Keeler & Long Epoxy Primer No. 6548 (seal coat), 6548S (surfacer), and a finish coat of Keeler & Long E-1 Series Epoxy,

- Imperial Nutec No. 11S Surfacer and a finish coat of Imperial Nutec No. 1201,
- Surface Starglaze 2011S and a finish coat of Carboline 890, and
- Keeler & Long No. 6129 and a finish coat of Keeler & Long No. 5000

Paint Debris Generation and Transport:

Qualified coatings for debris generation used a ZOI of 5D based on testing of qualified coatings conducted by Westinghouse, WCAP-16568-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," June 2006. Qualified coating within the ZOI of a LOCA-generated break is postulated to fail as particulate. These qualified coatings include coatings on walls, floors, structural steel, and uninsulated piping.

Coating ZOI:

The NRC SER on the NEI methodology (NEI 04-07) states, "The staff position is that the licensees should use a coatings ZOI spherical equivalent determined by plant-specific analysis, based on experimental data that correlate to plant materials over the range of temperatures and pressures of concern, or 10D (10 pipe diameters)." The WCAP-16568-P provides experimental data for DBA-qualified/acceptable coatings that show that use of a 5D ZOI is conservative for DBA qualified/acceptable coatings. Specific coatings tested in the WCAP-16568-P are the same as, or are similar to the DBA-qualified coatings used in the MPS3 containment.

MPS3 surfaces with DBA qualified/acceptable coatings subject to a LOCA jet include carbon steel surfaces such as structural steel and liner plate, concrete walls, and concrete floors.

DBA-qualified coatings for MPS3 are summarized above. All these coatings were tested by the manufacturer under simulated operating and incident conditions and certified to be DBA-qualified.

WCAP-16568-P tested steel coupons coated with Keeler & Long White Epoxy Primer No. 6548/7107 and a finish coat of Keeler & Long D1 9140 Epoxy Hi-Build White Enamel. This combination is nearly identical to the original coating of steel coating used in the MPS3 containment.

Concrete walls and floors in the MPS3 containment have original coatings that are DBA qualified and are similar to the coatings for concrete surfaces tested in WCAP-16568-P. Replacement coatings systems for concrete walls and floors at MPS3 are the same as or similar to the original coatings for concrete surfaces.

Replacement and maintenance coatings at MPS3 for steel surfaces inside containment are DBA-qualified epoxy coatings. These include Keeler & Long White Epoxy Primer No. 6548/7107 with a finish coat of Keeler & Long E-1 or D-1 Series. Testing of steel coupons in the WCAP included testing with a prime coat of Keeler & Long White Epoxy Primer No. 6548/7107 and a finish coat of Keeler & Long D1 9140 Epoxy Hi-Build Enamel. The coating on these coupons nearly matches the replacement coatings allowed in containment.

Replacement coatings systems allowed for steel and concrete surfaces in containment are DBA-qualified systems and are expected to perform similarly to the coating systems tested in the WCAP. Thus, use of a 5D ZOI for these coatings is conservative.

The specific coating systems tested by Westinghouse were all DBA-qualified/acceptable coating systems and the test conditions adequately simulated the containment and RCS parameters. The test apparatus was set up to simulate an instantaneous pipe break with a 30 second blowdown time which is postulated to occur for the limiting double ended guillotine LOCA at a typical PWR.

The pressure of the fluid source in the test was 2200 psia and the normal operating pressure of the RCS is 2250 psia. The temperature of the fluid source for the testing was 530°F, while the reactor coolant vessel inlet and outlet temperatures are 557°F and 617°F, respectively. The conditions were chosen so as to be directly applicable to PWRs without any scaling. The small differences in pressure and temperature between the test setup and the MPS3 RCS are not considered significant for the purposes of determining the amount of coating destroyed by a LOCA jet.

All DBA-qualified/acceptable coatings were required to undergo rigorously specified testing as detailed in the WCAP. Per the WCAP, "DBA qualified/acceptable epoxy coatings will perform similarly, regardless of the manufacturer or the specific formulation. The basis for this similarity in performance is derived from the acceptance testing that coatings systems undergo to earn the label of 'DBA Qualified/Acceptable coating system....' " The WCAP adequately justifies that all DBA qualified/acceptable coatings are expected to perform similarly to those specific qualified coating systems tested.

All of the coatings tested for the WCAP testing program were newly applied coatings and were not irradiated prior to jet impact testing. Qualified coatings installed in the MPS3 containment are approximately 25 years old and have been exposed to normal containment conditions including temperature and radiation environment for normal operations. Maintenance of those coatings has consisted of periodic visual inspections and removal and replacement of damaged or detached qualified coatings. The coatings applied to structural steel and concrete or masonry walls at MPS3 were DBA qualified when they were applied and they have been maintained consistent with industry standards. Coatings that have remained adherent and visually intact are considered qualified/acceptable for future use and are considered to meet all the requirements of qualified/acceptable coatings and are expected to perform no differently than the coatings tested in the WCAP under similar jet impact conditions.

Adhesion testing has been performed at four nuclear plants and reported in Electric Power Research Institute (EPRI) Report 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings," August 2007. This testing showed that aged, visually intact, DBA-qualified coatings (from various manufacturers) that exhibit no visual anomalies (e.g., no flaking, chipping, or blistering) continue to exhibit system pull-off adhesion at or in excess of the originally specified minimum value of 200 psi. As a result, the WCAP testing with newly coated samples also applies to the existing DBA-qualified/acceptable coating in containment at MPS3.

The WCAP concludes that, based on the data presented, the jet impingement data supports use of a 5D ZOI for all original and replacement qualified coatings at MPS3. As described above, this data is applicable to MPS3 and thus the use of a 5D ZOI for qualified coatings is conservative and acceptable.

All unqualified coatings in containment are assumed to fail due to post-LOCA conditions. All coatings debris (qualified and unqualified) is assumed in the analytical debris transport calculation to be 10 μm particulate. All coating debris is assumed to transport to the strainer and contribute to head loss. This is consistent with the guidance in the NRC SE requiring coatings debris for fiber plants (MPS3 is a high fiber plant) to be highly transportable. All coatings are modeled as epoxy since epoxy has the lowest density (and thus the highest potential to transport) of the major coating types found in the MPS3 containment (including epoxy, inorganic zinc, and alkyds).

Coating Surrogate Material for Testing:

The replacement strainer design was tested at AECL's Chalk River Laboratory in Canada using walnut shell flour as the surrogate debris source to simulate coating debris. NRR staff witnessed portions of the model testing. A trip report for this visit to AECL documents the staff's observations (ADAMS Accession No. ML062020596). The walnut shell flour used had a size range from 2 to 60 microns with an average particle size of approximately 23 microns. The density of the walnut shell flour is somewhat lower than that for coating debris (81 lbs/ft3 vs. 94 lbs/ft3), and therefore it will transport as readily as coatings debris. The AECL testing using the walnut shell flour is adequately representative of coatings debris generation and transportability at MPS3. For additional discussion on the acceptability of the use of walnut shell flour see Section F of this response.

Leaching of chlorides from coatings has been addressed under industry programs. Epoxy coatings are chemically inert in the post-LOCA containment sump pool and leaching of chlorides will not result in a significant quantity of reactant. Zinc coatings (primers) may release elemental zinc to the post-LOCA containment sump pool but industry testing has shown that there is very little zinc reaction with the post-accident sump fluid chemistry. Non-epoxy coatings consist of alkyds, urethanes, and acrylics. The amount of these coatings inside containment is generally limited to selected OEM equipment such as electrical junction boxes and represents a small amount of the material in containment. These coatings do not represent a significant debris load in the sump. Furthermore, these coatings are, as a class, chemically benign and do not react in the post-LOCA sump fluid. They have been evaluated in industry programs to have a negligible impact on post-LOCA chemical precipitate production.

Containment Coatings Condition Assessment:

A general condition assessment of coatings inside the MPS3 containment building was performed during the refueling outage in the spring of 2007. A protective coating specialist completed a visual inspection, which identified unqualified and unacceptable coatings in the containment building. The surface areas of identified unqualified coating were approximated. This data was combined with information from a prior condition assessment (performed in 1999) as the summary of unqualified and unacceptable coating materials. This information is used to determine the volume or quantities of coating material that may become a source of debris inside containment (following a postulated LOCA) and is used as input to calculations supporting the new sump strainer design.

EPRI Report TR-109937, "Guideline on Nuclear Safety-Related Coatings," states that, "Coatings degrade in manners that are easily detected visually and prior to detachment." The subsequent section in this guideline states, "The most effective means to conduct a thorough coatings condition assessment and detect coating degradation is through visual inspection."

EPRI Report 1014883, “Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings,” reports adhesion test data from existing qualified coatings in containment at operating nuclear plants. The report states, “Review of the adhesion test data confirms that aged, visually intact, design-basis-accident-(DBA-) qualified coatings (from various manufacturers) that exhibit no visual anomalies (i.e., no flaking, peeling, chipping, blistering) continue to exhibit system pull-off adhesion at or in excess of the originally specified (ANSI N5.12 and ASTM D5144) minimum value of 200 psi.”

Condition assessments (performed in the aggregate) are the result of comprehensive visual inspections of the coatings inside containment. There are no anomalous or large failures of coatings inside the containment building.

Based upon observed conditions, coatings inside containment have performed as expected. Consequently, there is no reason to believe that the existing coating systems will not continue to perform as designed, including during a postulated LOCA event.

There are three specific reasons that visual inspections are considered to be the most suitable means for performing these assessments.

- The tests are non-destructive.
- Visual inspections are consistent with ALARA guidance.
- Visual inspections provide a wider sample than local in-situ tests.

I. DEBRIS SOURCE TERM

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions. The GSI-191 program is described in a procedure. The program establishes overall standards for containment conditions relative to containment recirculation sump performance.

Latent Debris:

Due to the large fibrous debris load in the MPS3 containment, latent debris is a relatively small contributor to strainer head loss. A thorough latent debris inventory was done and a conservative bounding number was chosen for the debris calculations. It is expected that further latent debris inventories will not be required and that latent debris will be adequately controlled through housekeeping and containment cleanup. As necessary, latent debris will be sampled and quantified using a calculation of containment surface area developed for this purpose. A thin-bed debris load is postulated to form on the containment sump strainer and has been shown in head loss testing to produce the worst-case debris bed head loss.

Changes to the plant housekeeping procedure and to the containment closeout procedure have been made to explicitly describe containment housekeeping expectations for worksites and the general containment area. Training has been provided to plant staff and supplemental staff to emphasize the need for and awareness of the importance of maintaining a clean containment.

Foreign Material Control:

The containment housekeeping procedure has been updated to prevent leaving material in containment that will impact the strainer debris load. This procedural direction includes direction to set up debris barriers at work areas, cleanup of work areas at the end of each shift, remove barriers at the end of work, and to leave the work area cleaner than it was found at the start of the work.

The containment closeout procedure has been updated to require an inspection of containment for loose debris that could block the containment sump strainer; and, an inspection of the strainer for debris, damage, or blockage.

Permanent Plant Changes:

For permanent plant changes, the design review process has been updated to require that all design changes be reviewed using a series of detailed questions to determine if any potential debris source is to be put into containment. These questions are written to determine whether any debris source (e.g., fibrous or particulate material, coatings, stickers, particulate, aluminum, or calcium) is being introduced. If a debris source is introduced, the process requires that a detailed review be conducted to review the potential impact on ECCS sump strainer head loss.

The application of an unqualified coating system is not permitted inside the containment building. Small quantities of unqualified coatings on vendor supplied equipment may be allowed if added to the unqualified coating total maintained in a calculation by engineering. Coating systems used inside containment are required to comply with the containment coatings specification.

A coatings inspection and remediation procedure is also in place to ensure that the coatings inside containment remain within the requirements of the analysis.

Temporary plant design changes are subject to the design review process described above.

Insulation inside containment is controlled by Insulation Specifications as well as by various plant drawings. Any deviations from these specifications are subject to the design review process described above.

Signs and labels are controlled by procedure and require Engineering approval for the use of labels inside containment that are of a type (plastics, adhesives) that would compromise GSI-191 assumptions.

Maintenance Activities:

The controls on debris sources described above prevent maintenance activities from introducing unevaluated debris sources into containment that will be left during plant operation. As an added measure of assurance, maintenance activities in containment are controlled through work order screening before each outage to determine whether debris may be introduced to containment.

Section 5.1 of the SER describes five design and operational refinements related to debris source term. No additional refinements were taken at MPS3. The application of each of these refinements is summarized below.

Housekeeping and FME Programs:

Housekeeping and Foreign Material Exclusion (FME) programs are in place at MPS3 to maintain cleanliness of containment and to protect plant equipment by preventing entry of foreign material. Tags and stickers are controlled by procedure and the strainer is designed for bounding amounts of such items. A formal survey of stickers was done to verify the amounts of foreign material in containment and a conservatively large surface area was added to the strainer to account for blockage by foreign material such as stickers, labels, and tags. Sufficient guidance exists to prevent addition of significant quantities of additional tags or stickers to containment.

Latent debris has been sampled twice in containment and may be sampled again if deemed necessary to ensure that the total amount of latent debris in containment remains below the amount used in the strainer design. This sampling is not necessary on a regular basis because the sampling that has been accomplished has demonstrated a significant margin to the acceptance criteria. Latent fiber is an insignificant fraction of the total fiber load and so can effectively be ignored. Latent particulate is only a small fraction (approximately 10% by volume) of the total particulate load used in the strainer design and so is likewise not expected to be a significant contributor to strainer head loss.

Debris Source Term Refinement:

The following debris source term refinements discussed by the NRC SE, but which were not applicable to MPS3 or were determined to not have a consequential increase in quality and safety in addressing GSI-191 at MPS3, were not performed.

- Insulation Change-Out
- Existing Insulation Modification
- Other Equipment or Systems Modification
- Coatings Program Modification or Improvement

J. SCREEN MODIFICATION PACKAGE

The ECCS pump suction lines are in a depressed sump that was surrounded by a vertical screen with 3/32" openings and approximately 240 ft^2 of surface area.

The replacement ECCS strainer (installed spring 2007) is a finned strainer manufactured by AECL. It has a surface area of approximately 5041 ft^2 and is fully submerged on the start of recirculation. The strainer is composed of 17 modules. Each module has 5 vertical fins. Each of the fins is nominally 8 inches apart (center to center distance). The fins are perforated and corrugated stainless steel with 1/16" circular openings. The strainer sits above the sump pit and extends out onto the containment floor. Debris collects on and between the fins and filtered water passes into the fins and drops vertically into a channel allowing water flow into the sump and to the ECCS suction pipes. The strainer has a solid cover plate installed approximately 8 inches above the fins. This cover plate protects the fins from inadvertently dropped debris during outages and provides a work platform.

The fins on the strainer are nominally 7 inches off the containment floor. The support structure for the strainer comprises a nominal 7-inch curb.

There are no vents through the strainer control surfaces that connect the volume internal to the strainer to the containment atmosphere above the containment minimum water level. Level and temperature instruments penetrate the strainer control surface but do not provide any air ingestion path since they do not connect the internal volume of the strainer to the containment atmosphere.

The strainer is a passive device with no moving parts. As such, there are no internal sources of failures and an active failure of the strainer does not need to be considered. The original screen had a perforated divider screen between the two ECCS suction trains. The purpose of this divider screen was to separate the sump into two halves so that failure of, or clogging of, one half of the screen did not prevent flow to both trains of RSS pumps. This was reasonable with a licensing basis that postulated 50% screen blockage. The ECCS systems are connected downstream of the strainer and thus the divider plate was never intended as a train separation measure in case of structural failure of one half of the strainer. The divider plate was only in place to allow for water passage through the clean half of the strainer to both trains of RSS pumps in the event of clogging of one half of the strainer.

This design feature was evaluated for the new strainer design in light of the mechanistic debris generation and transport analysis. In the new strainer design, if only one train of RSS pumps is operating, roughly half of the flow would be required to pass through the divider plate to the operating pump. The other half would come from the strainer modules connected directly to the active pump intakes. In other words, half of the flow that passes through the nominally 5000 ft^2 strainer would have to pass through a perforated divider plate having a screen area of perhaps 10 to 50 ft^2. Even if only 0.1 percent of the roughly 800 ft^3 of fibrous debris postulated to arrive at the strainer passed through the main strainer, this would result in a bed thickness of roughly 0.2 inches on a 50 ft^2 divider plate. The exact fraction of fiber passing through the strainer could be greater than 0.1 percent. Because of the relatively high approach velocity through the divider plate, the head loss through that plate would be greater than through the rest of the strainer, which would effectively disable half of the strainer and cause a higher than acceptable head loss for the operating pumps.

No pipe whip or jet impingement concerns exist in the vicinity of the strainer. The replacement strainer is thus not subject to damage from pipe whip or jet impingement. The strainer is designed to withstand design basis earthquake loading and hydraulic loading prior to and during operation. The strainer is a robust structure that is resistant to damage from any falling debris. In addition, the cover plate installed above the strainer will also protect the strainer from falling debris. Periodic inspections of the strainer for gaps and breaches are conducted per the Technical Specifications, and will detect any incidental damage to the strainer during normal operation.

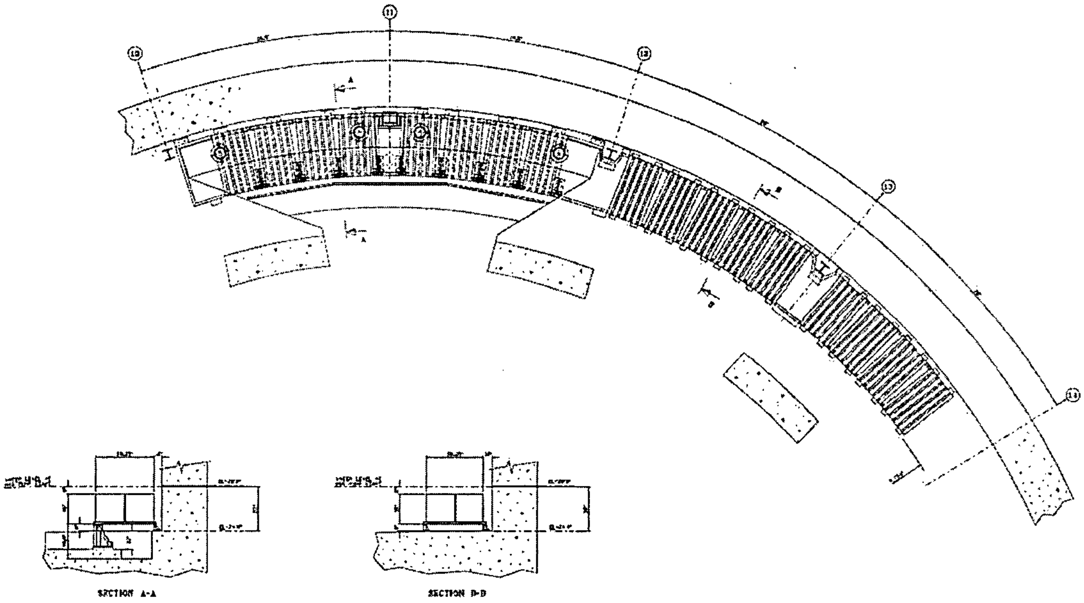
The existing Failure Mode Analysis documented in the MPS3 Updated Final Safety Analysis Report (UFSAR), Table 6.3-10, does not consider failure of the sump trains of strainer modules. As such, the existing strainer partition plate was not considered a necessary part of the design to ensure redundancy. Since there is no credible failure that could cause damage to part of the strainer assembly, there is no need to separate strainer trains in the new design.

No active strainer design was considered for use at MPS3 due to the relatively large area for replacement strainer installation and the relatively large available margin to suction line flashing for the RSS pumps. A properly designed passive strainer adequately ensures compliance with the long-term cooling requirements of 10 CFR 50.46 (b)(5).

K. SUMP STRUCTURAL ANALYSIS

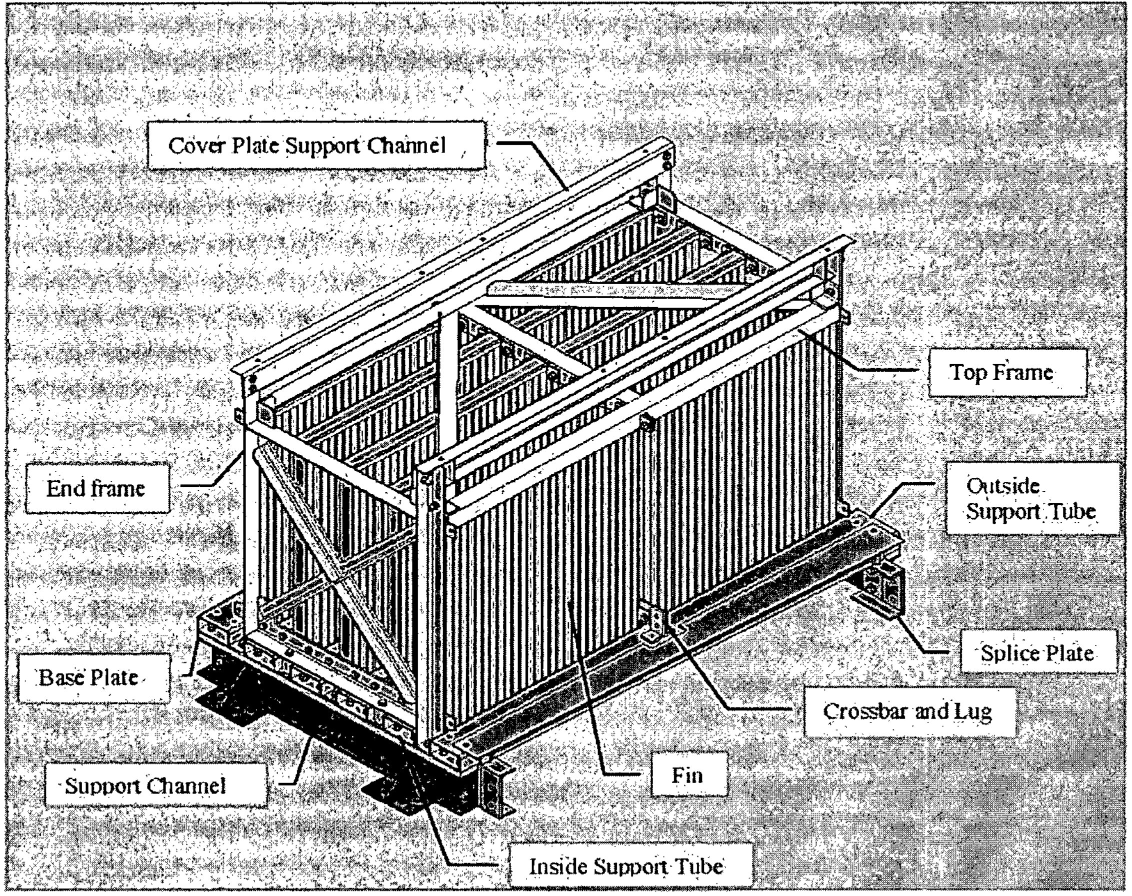
The sump strainer structure consists of 17 interconnected modules anchored to a support frame, which is internally anchored to the containment structure basement slab. The strainer is located outside of the containment structure crane wall in the annulus between the crane wall and the containment exterior wall. The 17 modules sit partially over the depressed sump area and extend via a plenum created by the structural framing over the basement slab level, as shown in the Figure K-1.

Figure K-1: Strainer Structural Framing Layout



The individual modules consist of 10 sections of strainer fins bolted to the module framing. The strainer fin sections consist of perforated corrugated stainless steel plate with solid plate edges, the module framing consists of stainless steel tube and channel sections with a combination of bolted and welded connections. See Figure K-2.

Figure K-2: Strainer Module Sections



The sump strainer is sufficiently removed from pipe whips, jets or missiles that they do not affect the design of the strainer.

Inputs that have been used in the structural design include:

- Maximum differential strainer suction pressure = 10 psi
- Maximum sump water temperature = 260°F
- Maximum containment air temperature = 350°F
- Maximum containment pressure = 59.7 psig
- Cover plate live load = 60 psf

Structural analysis uses the methods of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NF Class 3 Component Supports as a guideline. The strainer is not a code component and it is replacing the sump screens, which were designed and installed to the AISC code. The strainer modules are analyzed using the ANSYS code utilizing a combination of shell and finite elements with linear elastic properties. Hydrodynamic loads from the response of a coupled water mass are included in the structural design. Required thermal growth is accommodated by the use of slotted connections with bushings and bolted connections.

Seismic analysis of the containment sump strainer is complete. The sump strainer structural analysis considers the following loadings, Dead Weight, Live Load, Operational Based Seismic Loading, Safe Shutdown Based Seismic Loading, Suction Pressure, Hydrodynamic Loading, and Thermal Loading. The governing load combination for the strainer design is the Dead Weight + Suction Pressure + Safe Shutdown Earthquake Inertia + Safe Shutdown Earthquake Hydrodynamic Loads. Seismic responses are developed and the three directional responses are combined utilizing the square root of the sum of squares (SRSS) method in accordance with the unit FSAR requirements.

Tables K-1, K-2 and K-3 summarize analyzed stress, and its comparison with allowed stress for various strainer components.

Table K-1: Fin Component Stress Summary

Component	Maximum Stress (ksi)			
	Membrane		Membrane + Bending	
	Stress	*Limit*	*Stress*	*Limit*
Perforated Sheet	3.15	25.6	12.76	38.4
Top End Cap	1.82		2.79	
Bottom End Cap	3.06		3.65	
Inside/Outside Plate	0.79		3.28	
Top End Plate	2.56		2.79	
Bottom End Plate	1.84		3.28	
Bottom Mounting Lug	1.02		2.04	
Top Mounting Lug	<1.02		<2.04	

Table K-2: Strainer Module Plate Elements Stress Summary

Component	Maximum Stress (ksi)			
	Membrane		Membrane + Bending	
	Stress	*Limit*	*Stress*	*Limit*
Support Tubes	12.99	25.6	36.56	38.43
Base Plate	2.32		17.66	
Crossbar	10.73		10.88	
Crossbar Lug	21.39		33.13	

Table K-3: Strainer Module – Beam Elements

Component		Tension (ksi)		Shear (ksi)		Compression (ksi)		Bending-Y (ksi)		Bending-Z (ksi)		Interaction of Axial Compression & Bending (ksi)	
		Stress	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*	*Stress*	*Limit*
Top Frame	Side Beams	0.00	21.15	0.12	14.10	0.51	5.95	4.12	21.15	6.00	21.15	0.564	1
	Diagonal Bracing	0.00		0.02		0.46	7.74	1.15		0.84		0.153	
	Centre Beam	0.00		0.10		0.52	8.57	0.41		1.78		0.164	
	Grating Support Channel	0.00		0.01		0.29	5.49	0.61		0.24		0.093	
End	Column	0.00		0.63		5.50	8.91	2.17		1.56		0.794	
	Top Beam	0.10		0.86		0.07	8.57	2.59		13.37		0.763	
	Bottom Beam	0.08		1.91		0.71	8.57	11.19		1.94		0.704	
	Diagonal Cross Bracing	0.00		0.64		1.42	6.77	1.29		8.28		0.663	

The strainer will be maintained in accordance with plant procedures. The procedures require verification that the sump strainer is ready for service and free of any detrimental damage, which might have occurred during plant maintenance activities on a refueling basis interval, in accordance with Technical Specifications.

Leak-before-break was not used in analyzing jet impingement loads for the strainer. The strainer is physically removed from any high energy line breaks.

L. UPSTREAM EFFECTS

The objective of the upstream effects assessment is to evaluate the flowpaths upstream of the containment sump for holdup of inventory that could reduce flow to and possibly starve the sump.

Postulated worst-case break locations include breaks in cubicles 1 and 4 that are selected due to close proximity to the sump and a break in cubicle 2, which is selected due to the worst-case debris load. Walkdowns have been performed in containment to identify flowpaths and chokepoints that could prevent water from getting to the containment sump pool. In addition, a detailed calculation has been performed to identify flow paths from spray headers to the containment floor and to quantify the flow rate of each path as a function of time. This calculation determines the total flow of water on the containment floor and is used in determining minimum water level when the RSS pumps start. The walkdowns revealed no significant choke points between the postulated break locations and the containment sump. Major volumes of water holdup are summarized below.

Much of the floor space in containment is grating which avoids the holdup of significant volumes of water on floors above the containment basement. No significant water can be stopped from flowing to the containment pool by debris blocking this grating due to the large surface area of grating in containment.

Water is assumed held from reaching the containment sump in the following major volumes:

- Loop cubicles at elevation 3'8" will collect water due to kickplate curbs.
- Liquid Films on solid floors and heat sink surfaces are assumed to hold water.
- Refueling Cavity collects quench spray flow and recirculation spray flow, and drainage of the refueling cavity is not credited.
- Reactor Cavity and Incore Instrumentation Tunnel will fill with water (approximately 12,800 gallons) prior to additional water overflowing this

volume and reaching the containment floor. Flows from the limiting breaks are assumed to fill this volume prior to spilling onto the containment floor.

- Containment Atmosphere (water vapor) will hold water from reaching the sump.

No debris racks are installed in containment. Curbs on floors with the potential for water holdup have been accounted for in the water holdup calculation.

M. DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

The flow paths downstream of the containment sump were analyzed to determine the potential for blockage due to debris passing through the sump strainer. The strainer opening size is 1/16-inch. The acceptance criteria were based on WCAP-16406-P, Draft Rev. 1.

The strainer design ensures that gaps at mating surfaces within the strainer assembly and between the strainer and the supporting surface are not in excess of the strainer hole size of 1/16-inch.

These evaluations were done for all components in the recirculation flow paths including, but not limited to, throttle valves, flow orifices, spray nozzles, pumps, heat exchangers, and valves. The methodology employed in this evaluation is based upon input obtained from a review of the recirculation flow paths shown on Piping and Instrument Diagram Drawings and plant procedures. The steps used in obtaining the flow clearance are as follows:

- Determine the maximum characteristic dimension of the debris (clearance through the sump strainer).

- Identify the recirculation flow paths.

- Identify the components in the recirculation flow paths.

- Review the vendor documents (drawings and/or manuals) for the components to obtain flow clearance dimensions.

- Determine the blockage potential using a comparison of flow clearance through the component and flow clearance through the sump strainer.

- Identify the components that require a detailed evaluation and investigation of the effects of debris on their capability to function.

Components were classified into the following three categories:

- Components with flow clearances equal to or smaller than the minimum strainer opening plus 10% (i.e., 1.10 x 0.0625 inches) or 0.069 inches
- Components with flow clearances larger than 0.069 inches up to 0.125 inches (twice the strainer opening size)
- Components with flow clearances larger than 0.125 inches

Components with clearances smaller than the sump strainer hole size include:

• Safety Injection and Centrifugal Charging Pump Clearances	Wear Ring Interstage Bushing	0.010 inches 0.010 inches
• Recirculation Spray Pump Clearances	Wearing Ring-First Stage Impeller Wear Ring-Series Impellers	0.018 inches 0.020 inches
• Containment Sump Level Transmitters' Clearance	Between float and shaft	0.056 inches

The downstream wear calculation evaluates component wear using the guidance in WCAP-16406-P, Draft Rev. 1.

- Wear in the RSS pumps, SIH pumps, CHS pumps, manually throttled valves, motor operated valves, orifices, and heat exchangers are included in the component wear evaluation. The wear effect on performance of these components is evaluated.
- Evaluation of the downstream instrumentation, including temperature indicators, pressure indicators, flow indicators, and containment sump level elements for potential blockage due to the presence of debris is included in the calculation.

Pumps:

The abrasive and erosive wear of a pump's internal subcomponents resulting from pumping debris-laden water will cause an increase in the flow clearances of the pump. The increase in flow clearances is evaluated for impact on hydraulic performance of the pump. A second issue associated with wear is the changing system resistance curve due to wear of components such as valves and orifices. The wear results from the calculation indicate that all valves, plate orifices, multi-stage orifices, and containment spray nozzles pass the criteria and therefore, the effect on system flow rates is negligible.

Hydraulic performance and mechanical dynamic performance of each ECCS pump is found acceptable because the total abrasive and erosive wear of small clearance areas on the ECCS pumps is less than the wear allowance for replacement, and are therefore acceptable. Thus, the hydraulic performance of the ECCS pumps will not be impaired due to abrasive and erosive wear of pump subcomponents while pumping debris-laden water for 30 days post-LOCA.

Wear on the mechanical seal on each of the ECCS pumps has been calculated as approximately 0.142 inches.

For the RSS pumps, the mechanical seal has a tandem packing design with a non-clogging single coil spring design that is not affected by the debris build up. The tandem seal is pressurized between the seals with clean water for the first 7 days of the accident by an external seal tank. After 7 days, debris bypass is significantly reduced and is likely negligible.

The upper outboard seal, a feature of the tandem packing design, is provided to preclude excessive leakage in the unlikely case of a lower inboard seal failure. Therefore, the wear calculated for the mechanical seals' primary ring is acceptable and because of the mechanical seal design, wear would not adversely affect the mechanical seal performance.

For the SIH and CHS pumps, the shaft seals are designed with a bushing seal (backup seal) to limit the leakage flow in case of a catastrophic primary seal failure. Therefore, the wear calculated for the mechanical seal's primary ring is acceptable and because of the inherent design features, the calculated wear would not adversely affect the mechanical seal performance.

Heat Exchangers:

The tube wall thickness of the RSS heat exchanger tubes minus the tube wall thickness lost to erosion is greater than the minimum tube wall thickness required to withstand the internal tube design pressure. Therefore, the heat exchanger tubes have sufficient tube wall thickness to withstand the erosive effect of the debris-laden water for a period of 30 days post-LOCA.

Other components:

All manually throttled valves, flow elements, plate orifices, barrel orifices, and containment spray nozzles in the recirculation flow path pass the criteria set forth per WCAP-16406 Rev. 0 and therefore, the calculated wear will have insignificant effect on the system flow. No further evaluation is required. No piston check valves are required to close during recirculation so no further evaluation is required.

Instrumentation:

Instrumentation that is mounted horizontally on the piping is not susceptible to failure due to plugging. The velocity of the fluid as well as the orientation of the instrument in the pipe will allow the debris to continue flowing beyond the instrumentation. Therefore, the identified instrumentation will not be adversely affected by debris in the recirculation flow path.

The containment sump level elements are float devices. The clearance between the float and the shaft on which the float rises is 0.056 inches. When debris-laden fluid is entering the sump, these level transmitters have been analyzed for plugging and have been determined to be unlikely to plug as described below. These devices provide a computer indicator in the control room indicating the containment sump water level. These devices are not interlocked with any other components and will, therefore, not cause the failure of the recirculation flow path post accident. However, the operators use the containment sump level indicators for indication of sump level for items such as event diagnosis and determination of readiness of recirculation pumps to start if automatic start does not occur. The location of the floats protects them from any jet impingement concerns since they are outside the break zone of influence. The floats are also partially enclosed by structural steel that will protect them from damage from floating debris. Each of the two level elements (LE22A and LE22B) is comprised of three floats that are separated both vertically and horizontally. Float movement will be gradual with water level changes and the floats will stay on top of the water column until they are at or near their individual indicating limit and then will be submerged. Once submerged, plugging is more likely than when they are floating on the water level. However, once submerged, the float is at or near its indicating limit and thus is providing no further useful information. Plugging of the gap between float and shaft due to debris is highly unlikely before the float is submerged in the water column. Wear of the gap between the float and the shaft is not a concern since flow velocities are near zero in the vicinity of the floats.

The evaluation of downstream wear was completed for WCAP-16406, Draft Rev. 1. No hardware changes were found to be necessary. The changes still required to the wear evaluation as a result of the recent NRC approval of Revision 1 to WCAP-16406 are in progress, and are being expedited.

N. DOWNSTREAM EFFECTS - FUEL AND VESSEL:

WCAP-16793, Rev. 0 has been published concerning the impact of fibrous, particulate, and chemical precipitate debris on the fuel and long-term cooling. The WCAP results provide reasonable assurance that long-term core cooling will be established and maintained post-LOCA, considering the presence of debris in the RCS and core. The debris composition includes particulate and fiber debris, as well as post-accident chemical products.

The results of WCAP-16793 are applicable to MPS3. The WCAP evaluated the following three topical areas:

- fuel clad temperature response to blockage at the core inlet
- fuel clad temperature response to local blockages or chemical precipitation on fuel clad surface
- chemical effects in the core region, including potential for plateout on fuel cladding

General Conclusions of Assurance of Long-Term Core Cooling and Their Basis:

The WCAP states that the evaluation of the three areas discussed above, in conjunction with other information, provides a reasonable assurance of long-term core cooling with debris and chemical products in recirculating fluid. The discussion of the basis for these general conclusions is in the items below under this section. DNC concluded that this basis is applicable to MPS3 by performance of a plant specific evaluation discussed in more detail by the next section concerning applicability of WCAP-16793-NP.

i. Blockage at the Core Inlet and Adequate Flow:

Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Test data has demonstrated that any debris that bypasses the screen is not likely to build up an impenetrable blockage at the core inlet. While any debris that collects at the core inlet will provide some resistance to flow, in the extreme case when a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue.

ii. Decay Heat Removal with Debris Collection at Fuel Grids:

Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the screen is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does not occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue.

iii. Fibrous Material on Fuel Cladding Surfaces:

Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling.

iv. Prediction of Chemical Deposition from Chemical Effects on Fuel Cladding:

Using an extension of the chemical effects method developed in WCAP-16530-NP to predict chemical deposition of fuel cladding, two sample calculations using large debris loadings of fiberglass and calcium silicate were performed. The case demonstrated that decay heat would be removed and acceptable fuel clad temperatures would be maintained.

v. Mixing Volumes and Adequate Boric Acid Dilution:

As blockage of the core will not occur, the mixing volumes assumed for both the current licensing basis and boric acid dilution evaluations will remain unaffected by debris and chemical products transported into both the RCS and core by recirculating coolant from the containment sump. Therefore, the current accepted licensing calculations that demonstrate appropriate boric acid dilution to preclude boric acid precipitation remain valid.

Site-Specific Applicability Review of the WCAP-16793-NP General Conclusions:

DNC concluded the applicability of the WCAP-16793-NP to MPS3 by performance of plant specific evaluations that are discussed in more detail by the balance of this section. This effort demonstrates all of the WCAP evaluations and conclusions are directly applicable to MPS3. It provides a reasonable assurance that for MPS3 the long-term core cooling will be established and maintained post-LOCA, even when considering the presence of debris in the RCS and core. A detailed plant specific review of the following five effects is included.

- Blockage at the Core Inlet
- Collection of Debris on Fuel Grids
- Collection of Fibrous Material on Fuel Cladding
- Chemical Deposition on the Fuel Cladding
- Boric Acid Precipitation

i. Blockage at the Core Inlet:

The AECL strainer design installed at MPS3 has holes with a diameter of 1/16" inch (0.0625 inches). This is bounded by the assumption made in Section 2.1 of WCAP-16793-NP that the replacement strainers will have a hole diameter on the order of 0.1 inches.

Reduced scale testing conducted at AECL for other plants in the Dominion fleet (i.e., Millstone Power Station Unit 2, North Anna Power Station and Surry Power Station) included bypass testing, which determines the maximum amount of fiber bypass that would occur for the AECL replacement strainer. Fiber bypass testing for Millstone Power Station Unit 2 was conducted with the maximum fiber load and no added particulate. The amount of fiber that passed through the strainer was so low that for accurate determination of concentration and size, a scanning electron microscope (SEM) evaluation was required. SEM analysis of the fiber bypass test results showed that 90% of the fibers that bypassed the strainer were less than 1.2 mm long and the maximum length of fiber that bypassed the strainer was 2 mm. The strainer hole size is 1/16 inch or 1.6 mm. Based on bypass test results, 99.7% of the fibers were filtered on the first pass through the strainer. While plant specific bypass testing has not been performed for MPS3, the results of the Millstone Power Station Unit 2 bypass testing summarized above and the similarity in strainer design between Millstone Power Station Unit 2 and MPS3 provide confidence that these results are applicable to MPS3. This is entirely consistent with the observations of bypass testing discussed in Section 2.1 of WCAP-16793-NP.

A bounding WCOBRA/TRAC analysis of blockage at the core inlet is contained in the WCAP-16793-NP. The parameters of this analysis were selected to bound the US PWR fleet by modeling a limiting break type. The analysis uses a double-ended cold leg break that limits flow at the core inlet combined with the faster debris build-up that occurs for a high flow hot leg break. Also the limiting vessel design was modeled, which was the Westinghouse downflow plant. As stated in Section B.1.3 of Appendix B of WCAP-16793-NP, downflow plants are the most limiting design since the only means for limited flow to enter the core is through the lower core plate. MPS3 is an upflow plant, where flow may enter the core through the Baffle/Barrel region, and therefore the design is non-limiting with respect to core inlet flow and the WCOBRA/TRAC analysis presented in WCAP-16793-NP bounds MPS3.

The WCOBRA/TRAC analysis demonstrates that sufficient liquid can enter the core to remove core decay heat once the plant has switched to sump recirculation with up to 99.4 percent blockage at the core inlet.

ii. Collection of Debris on Fuel Grids:

As discussed above, the bypass testing of the AECL strainer design is entirely consistent with the WCAP-16793-NP conclusion, which states that it is unlikely the combination of fibrous and particulate debris will collect in numerous grid locations or that flow will be restricted enough to challenge long-term core cooling.

The WCAP-16793-NP contains ANSYS and first-principle calculations that demonstrate that the fuel rods will continue to be cooled even with significant blockages around the fuel grids. These analyses demonstrated that even with a completely blocked grid strap, core decay heat was adequately removed. As stated in Section C.4 of Appendix C to WCAP-16793-NP, the parameters for these calculations were derived from the WCOBRA/TRAC analysis, the results of which bound post-LOCA long-term core cooling clad temperatures for the entire US PWR fleet. Thus, these calculations bound MPS3 and the numerical and first principle analyses demonstrate that the general conclusion surrounding core decay heat removal applies to MPS3.

iii. Collection of Fibrous Material on Fuel Cladding

The WCAP-16793-NP refers to generic information for NEA.CNSI/R (95)11 "Knowledge Base for Emergency Core Cooling System Recirculation Reliability," February 1996, to support the conclusion that fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. The report reflects testing applicable to both NUKON™ and Knauf ET Panels. NUKON™ is essentially identical to the Transco low density fiberglass debris at MPS3 and thus the conclusions of the WCAP are applicable to MPS3.

iv. Chemical Deposition on the Fuel Cladding: *(in progress)*

WCAP-16793-NP documents an Excel spreadsheet called LOCADM that will calculate the deposition of chemical precipitates and the resultant maximum clad temperature. Preparation of an MPS3-specific calculation is in progress. When finalized, it is expected that the MPS3 specific calculation will confirm the conclusion of the WCAP that acceptable long-term-core cooling in the presence of core deposits is applicable to MPS3. Completion of this calculation is expected by the end of the first quarter of 2008.

v. Boric Acid Precipitation:

As discussed above under general conclusions, the evaluation of the potential for blockage for MPS3 is entirely consistent with the evaluations documented in the WCAP. Blockage will not occur for MPS3. The general conclusion of the WCAP that the current accepted licensing calculations demonstrate appropriate boric acid dilution, which precludes boric acid precipitation, remain valid and applicable to MPS3.

O. CHEMICAL EFFECTS:

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

The resolution of chemical effects at MPS3 has three main components. They are:

- An assessment of potential precipitates includes a determination of reactive material amounts present in the containment sump pool, the pH and temperature profiles in containment, and a review of existing test and scientific literature data. This determines which precipitates are likely to form in the post-LOCA sump pool. This assessment is complete.
- Bench Top Testing determines potential precipitates. *(In progress)*
- Reduced Scale Testing determines head loss due to potential precipitates. *(In progress)*

Overall Chemical Effects Strategy:

Westinghouse published WCAP-16530 Rev. 0, which has been accepted by the NRC staff as a conservative methodology to evaluate head loss from post-accident chemical precipitates. Dominion contracted with AECL to perform an assessment of potential chemical precipitates in the MPS3 sump pool that may contribute to head loss. This assessment by AECL uses MPS3 plant specific data on reactive materials, sump water volume, and post-LOCA debris constituents, bench top and precipitation test results from WCAP-16530, ICET test results, results from NRC sponsored research on chemical effects, and a thorough literature survey to determine the precipitates likely to form in the MPS3 containment sump pool post-LOCA.

The AECL assessment will be followed by appropriate bench top tests to verify the formation or lack of formation of expected precipitates. If necessary, reduced scale testing will be done for MPS3 to determine the impact of precipitate formation on debris bed head loss. It is expected that the precipitates formed would be added to the reduced scale test tank after a debris bed had formed to conservatively determine the long-term head loss in the tank.

ICET 2 most closely resembles the MPS3 containment sump pool. ICET 2 was a test of TSP buffered water with NUKON™ insulation and no calcium silicate.

The AECL assessment has concluded the following from a review of available data.

- Aluminum corrosion can give rise to the formation of an aluminum bearing precipitate but aluminum corrosion is inhibited by phosphates and silicates and the precipitate formed includes boron, which can affect the mass or flocculation properties of the aluminum bearing precipitate formed.

- Only low concentrations of iron, nickel, magnesium, and zinc dissolved into the simulated sump water and these species did not lead to the formation of significant amounts of precipitates.

- With TSP present, precipitates containing calcium, phosphate, and carbonate can form.

- Concrete does not appear to be a significant source of calcium.

- Precipitate formation is dependent on kinetic as well as thermodynamic properties.

- There is no evidence of direct chemical effects from paint debris. Radiolysis of organic compounds leaching from the coatings will lead to formation of carbonate species that could nominally lower the sump pH.

- WCAP-16530 suggests that sodium aluminum silicate is a possible precipitate. However, a review of the literature of thermodynamics and kinetics of aluminosilicate formation suggests its formation is unlikely under PWR post-LOCA sump water conditions.

If sodium aluminum silicate precipitate fails to form, the two precipitates of concern at MPS3 are aluminum hydroxide or oxyhydroxide and calcium phosphate.

Aluminum Hydroxide Precipitation:

As part of the assessment of chemical effects, AECL developed an aluminum release equation from the available aluminum corrosion data. The calculated aluminum release into the MPS3 sump water (including both unsubmerged and submerged aluminum) is expected to result in an aluminum concentration of approximately 5 mg/liter (ppm). This total dissolved aluminum concentration does not exceed the solubility of amorphous aluminum hydroxide. Thus, aluminum hydroxide precipitates are not expected to form in the MPS3 containment sump pool.

Calcium Phosphate Precipitation:

Calcium phosphate is highly insoluble. Significant quantities of phosphate will be present in the MPS3 containment sump pool due to the dissolution of the TSP buffer. ICET 3 included calcium silicate and TSP. A white precipitate (calcium phosphate) was observed to form early in the test and subsequent head loss testing at Argonne led to the issuance of NRC Information Notice (IN) 2005-26 to alert licensees to the adverse head loss impacts of calcium phosphate.

There is no calcium silicate insulation in the containment at MPS3. However, calcium may leach from concrete and fiberglass insulation in the post-LOCA sump pool.

In ICET 2 (30 days) containing TSP and NUKON™, no precipitate was observed to form and in tests conducted as part of WCAP-16530 (24 hour tests), no precipitate was observed to form in mixtures containing NUKON™ and TSP. In the absence of added calcium silicate, the amounts of calcium released from fiberglass are likely insufficient to result in the precipitation of calcium phosphate.

For MPS3, the bench top testing will determine whether calcium is released from the major sources of insulation in containment including Transco fiberglass and Microtherm. Uncertainty exists as to whether sufficient calcium will be released from concrete and insulation materials postulated to be present in the MPS3 containment sump pool to form a measurable amount of calcium phosphate precipitate. Bench top dissolution and precipitation testing will be done to determine how much calcium is released into the sump pool.

Dominion could modify the TSP buffer that is used to control the containment pool pH at MPS3 following a LOCA if that change becomes necessary to eliminate formation of calcium phosphate precipitate.

Reactive Materials in Containment:

Table O-1 shows the amounts (i.e., surface area) of potentially reactive materials that are:

- Submerged in the containment pool following a LOCA, and
- In the containment spray zone following a LOCA.

In addition to Table O-1, boric acid, LiOH (RCS), and TSP are postulated to be part of the containment sump pool since the RCS and RWST are borated, the RCS contains LiOH, and TSP is present in baskets on the floor of containment to buffer the sump pool water.

Section 3.B of this Attachment, Debris Generation, describes the sources of debris that are postulated to be dislodged by the LOCA jets and deposited in the containment sump pool. The sources of debris include fibrous insulation, coatings, Microtherm insulation, and latent debris.

Other materials in the containment that may be present in the containment sump pool include items such as copper (primarily in air systems piping) that has been shown to not be reactive in the post-LOCA environment, and leachates from coatings that are not postulated to form in significant quantities in the post-LOCA environment to produce precipitates. Other containment materials have been evaluated as having only an insignificant potential for becoming a part of the containment sump pool. Insignificant contributors include leaking oil (e.g., oil from pumps and hydraulic cranes) that tends to float on the surface of the water and not react to form precipitates, corrosion inhibitor in the closed cooling water systems that are not postulated to experience pipe breaks as a result of a LOCA, and air dryer desiccant that is not postulated to be released to the containment sump pool.

Dominion has no plans to replace or remove insulation from the MPS3 containment as part of the resolution of GSI-191 and no plans to modify the TSP buffer that is used to control the containment pool pH following a LOCA.

Table O-1: Surface Areas of Materials Subjected to Containment Spray and Submergence

Material	Surface Area Submerged (ft^2)	Surface Area Exposed to Containment Spray (ft^2) (does not include submerged material)
Aluminum	120	1080
Zinc (from galvanized steel)	20,000	360,554
Zinc (from inorganic zinc coating)	600	11,286
Carbon Steel (uncoated)	1000	--
Concrete (uncoated)	1000	1932
Fibrous Insulation	1390 ft^3	0

The only metallic paint used in containment is zinc primer (i.e., inorganic zinc coating listed in the table above). No scaffolding is stored in the MPS3 containment. All insulation is jacketed with stainless steel. The submerged fraction of galvanized material and zinc primer is conservatively estimated to be 5% of the total in containment.

There is only minimal uncoated carbon steel by design within the containment structure. An allowance of 1000 ft^2 allows for planned correction of existing conditions and unanticipated discovery of uncoated carbon steel, as well as existing uncoated carbon steel. The impact of this on chemical effects has been shown to be minimal by industry testing. For conservatism, all of this is considered submerged.

There is no uncoated concrete by design within the containment structure. One percent (1%) of the concrete in containment is assumed to be uncoated (1700 ft^2) to allow for correction of existing degradation. Total submerged uncoated concrete is assumed to be 1000 ft^2 and the total surface area exposed to containment spray is 700 ft^2. Uncoated concrete is postulated as created by the break jet. The break jet impacts a total of 1232 ft^2 of concrete surface area. All of this surface area is exposed only to containment spray and none is submerged.

The minimum sump water mass at MPS3 is 3,819,002 lb_m. This equates to a water volume of 63,439 ft^3 at the saturation temperature of the minimum containment pressure at the start of the accident (195°F). This is the water mass expected on the floor when the RSS pumps are effective. This total accounts for water losses due to holdup. Note that the RWST has approximately 560,000 additional gallons that spray into containment over approximately three hours to give a sump volume of 160,000 ft^3 (at 130°F).

Table O-2 shows the ratios of material to test tank water volume used in the ICET tests and the corresponding ratios of material to containment sump minimum water volume found in the MPS3 containment.

Table O-2: Comparison of Material Ratios Between ICET 2 and MPS3 Containment

Material	ICET Test Ratio	MPS3 Ratio	Comparison Factor (ICET Ratio / MPS3 Ratio)	% of material submerged		% of material un-submerged	
				ICET	MPS3	ICET	MPS3
Zinc in Galvanized Steel	8.0 (ft^2/ft^3)	6.0	1.3	5	5	95	95
Inorganic Zinc Primer Coating (non-top coated)	4.6 (ft^2/ft^3)	0.19	24.2	4	5	96	95
Inorganic Zinc Primer Coating (top coated)	0.0 (ft^2/ft^3)	0	N/A	-	-	-	-
Aluminum	3.5 (ft^2/ft^3)	0.02	175	5	10	95	90
Carbon Steel	0.15 (ft^2/ft^3)	0.016	9.4	34	100	66	0
Concrete (surface)	0.045 (ft^2/ft^3)	0.046	1.1	34	34	66	66
Fibrous Insulation	0.137 (ft^3/ft^3)	0.022 (ft^3/ft^3)	6.2	75	100	25	0

Based on Table O-2, the ICET material ratios exceed the MPS3 material ratios for all material. Formation of significant amounts of calcium phosphate precipitate does not appear to have occurred in ICET Test 2 despite the presence of the uncoated concrete and submerged fiberglass. The MPS3 fiberglass ratio is significantly under the ICET ratio and the MPS3 fiberglass is a nearly identical material to the NUKON™ used in ICET 2. No significant leaching of calcium likely occurred in ICET 2 based on the lack of calcium phosphate precipitate. This potential formation of calcium phosphate will be taken into account in testing planned for chemical effects resolution.

Uncoated concrete surface area is postulated to be similar in the MPS3 containment to the ICET tests. No concrete particulate was calculated for the MPS3 containment. The break jet is postulated to remove qualified coating from concrete surfaces. As demonstrated in the Westinghouse Chemical Effects testing documented in WCAP-16530, concrete is not a significant contributor to the formation of particulate precipitate. Any concrete particulate that may form as a result of the LOCA jet is heavier than water, sinks to the bottom of the containment sump pool, and is thus not included in the debris load. Additionally, concrete is a potential source of calcium. Formation of large amounts of calcium phosphate precipitate, however, does not appear to have occurred in ICET 2 despite the presence of the uncoated concrete and concrete particulate.

An industry-wide studied effect is the potential for coatings to contribute to chemical effects by leaching chemical constituents that could form precipitates or affect other materials (e.g., increase aluminum corrosion rates). This has been addressed by the PWR Owners Group for the industry (ADAMS Accession No. ML070950119) and its resolution accepted by the NRC. There is no significant leaching of chemicals from coatings to cause chemical precipitate formation or significant impact on head loss.

A related industry-wide concern is the potential for some of the coating chips to turn into a product that causes high head loss. Resolution of this item is addressed in WCAP-16793, discussed in Section 3.N above, which shows that the zinc primer at MPS3 will not cause formation of significant amounts of precipitate, non-epoxy coatings (alkyds, urethanes, and acrylics) are present in only relatively small amounts and are not expected to create chemical precipitates, and epoxy coatings are chemically inert and retain their structural integrity at temperatures up to 350°F, which exceeds the containment sump pool temperature. The vast majority of coatings in the containment are DBA-qualified and have been subjected to DBA testing which includes prolonged exposure to post-LOCA conditions. DBA-qualified coatings will not turn into a product that causes high head loss under post-LOCA conditions.

Unqualified coatings in the MPS3 containment are tracked and are present in relatively small amounts. High humidity and temperature conditions exist post-

LOCA and unqualified coatings are conservatively assumed to fail. Their failure is conservatively assumed to result in 10 micrometer particulate that fully transports to the strainer. In reality, much of the volume of these coatings will not fail as shown in EPRI Report 1011753, "Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings." Unqualified coatings that do fail will fail relatively slowly, will fail as a variety of particle sizes, will tend to settle, and will transport to the strainer over a significant time interval thus limiting their impact on head loss.

Considering all of these conservatisms, there is reasonable assurance that coatings will not turn into a product that causes high head loss and, if some of the unqualified coatings do turn into such a product, the amount will be very limited and not likely to have a significant impact on strainer head loss.

Containment Pool pH:

MPS3 uses TSP to neutralize the sump water in containment post-LOCA. The TSP is stored in baskets mounted on the floor of the bottom level of containment and dissolves as the coolant collects on the containment floor. The minimum amount of TSP required on the floor of containment is calculated to ensure that the long term pH of the containment sump is at least 7.

The best estimate of maximum pH values as a function of time post-accident are summarized in the Table O-3. The pH in the first minute is dependent on RCS water mixed with Safety Injection tank water. The pH gradually drops as RWST water is injected prior to the start of recirculation. Once mixing of the sump pool is complete (conservatively assumed to occur at the start of recirculation for maximum pH), the pH rises to as high as 8.5. Subsequently, the pH level drops as TSP is dispersed throughout the water in the containment (including holdup water) and the remainder of the RWST is injected via quench spray.

Table O-3: Containment Pool Maximum pH

Time	Maximum pH (at 77°F)
0-1 minute (prior to RWST injection)	6.6
1 min – 37 min (start of recirculation)	5.7
37 minutes (recirculation mixing complete)	8.5
165 minutes (RWST empty)	8.1
30 days (long term value)	8.1

ICET Test Comparison

MPS3 uses TSP as a buffering agent and has no calcium silicate in the debris load. Thus, ICET 2 is considered to be most similar to MPS3 conditions following a LOCA.

Table O-4: Comparison of ICET 2 Conditions with Post LOCA Conditions in Containment

Parameter	Millstone Unit 3	ICET Test 2
Boron Concentration	2900 ppm (maximum allowed in RCS)	2800 ppm
TSP Concentration	0.034 gmol/liter	0.0102 gmol/liter
pH	Long Term Minimum pH is 7.1 with a maximum long term pH of 8.5.	Average pH recorded during test is 7.3.

For ICET 2, the concentration of TSP was found using 3786 g TSP added and 949 liters of test tank water.

For MPS3, the concentration of TSP was found using 61,145 g-moles of TSP and the volume of water from the above discussion, 63,439 ft^3 or 1,796,630 liters for the SBLOCA.

The TSP concentration in the ICET Test 2 is the same order of magnitude as expected in the MPS3 containment. The higher TSP concentration in the MPS3 containment will contribute to a higher pH than was seen in the ICET test tank.

Differences exist between the ICET 2 and the MPS3 containment environment temperature. For the ICET test, the temperature was held at a constant 140°F. At MPS3, the sump temperature profile rises quickly to about 260°F in the first 200 seconds after the start of the accident. The temperature decreases from this peak to about 165°F by about 10 hours after the start of the accident and slowly drops from there over the remaining 30 days. Thus the peak temperature expected in the MPS3 containment sump water is higher than the temperature of the water in the test tank but the gradual temperature reduction brings the water temperature after 10 hours to roughly equivalent to the ICET tank water temperature.

The expected MPS3 containment water and air temperature profiles are given in the table below.

Table O-5: Maximum Containment Air and Water Temperature

Time (seconds)	Air Temperature (°F)	Time (seconds)	Water Temperature (°F)
0.00	120	0	130
0.01	150	60	259.979
1	200	200	262.153
10	280	900	254.5
325	280	1800	249.502
325.1	265	2200	247
1800	265	2600	241.5
6000	200	3600	233.319
20083	175	5400	217.305
86400	150	7200	203.946
432,000	125	10800	184.378
12,960,000	100	14400	180.111
31,536,000	100	18000	177.634
-	-	21600	175.134
-	-	25200	172.62
-	-	28800	170.184
-	-	32400	167.753
-	-	36000	165.34

Existing Margins for Chemical Effects:

MPS3 replacement strainer surface area is 5041 ft^2 compared to the actual tested area of 4290 ft^2. This creates a margin of 750 ft^2 of strainer surface area. Approximately 655 ft^2 of this surface area is for foreign material leaving a margin of approximately 95 ft^2.

No settling of particulate debris is credited in the analytical debris transport calculation and settling was minimized as much as possible during head loss testing by stirring of the test tank water. Much of the particulate debris is epoxy coatings with a density of approximately 94 lb/ft^3 that will promote settling.

Bench Top Testing:

The purpose of bench top testing involves the following goals:

- Demonstrate that the solubility behaviors of aluminum hydroxides and calcium phosphates obtained from the literature are reproducible and conservative under the expected site-specific conditions.
- Confirm that precipitates with the required properties (settling rate, particle size and filterability,) as specified in WCAP-16530 can be produced, prior to producing these materials on a scale large enough for head loss testing. In addition, tests will be carried out to determine the optimum storage time for the precipitates.
- Determine if the water chemistry that will exist during the chemical effects testing will have any effect on the properties of the walnut shells used in the tests as a surrogate for paint particulate.
- Determine if materials in the containment of MPS3 release an amount of calcium that is insufficient to produce a significant mass of calcium phosphate precipitate.

The bench top tests will consist of dissolution testing and precipitation testing.

Dissolution tests will determine the amount of calcium released from representative materials. Representative quantities of concrete (as coupons) and fiberglass will be placed in a flask with a solution of borated water at the appropriate temperature and pH. Samples of the water will be periodically measured for constituents such as calcium, silicon, aluminum, and properties such as pH, and conductivity. At the completion of the dissolution tests, a sample of the solution will be cooled and filtered. A representative amount of TSP will be added to the test vessel and the solution will be visually examined for precipitation, measured for turbidity, and filtered to determine precipitate formation.

Precipitation testing for aluminum hydroxide will be carried out under the following conditions:

- Conditions representative of those expected at the highest Al concentrations reached.
- Conditions representative of those expected when the pH and temperature change rapidly, as these rapid changes may induce precipitation.

P. LICENSING BASIS

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

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

- A change to the start signal for the RSS pumps was submitted and approved to ensure that the strainer was fully submerged and adequate NPSH existed for the RSS pumps prior to their start considering a mechanistic debris blockage analysis. This Amendment No. 233 was approved for MPS3 in NRC letter dated September 20, 2006 (ADAMS Accession No. ML062220160). Implementation of this change was completed by May 11, 2007, during the spring 2007 refueling outage.
- An amendment was approved and implemented for an administrative change to replace text in a surveillance requirement of "screen and trash rack" with the word "strainer", in Technical Specifications Section 4.5.2.d. This Amendment No. 240 was approved in NRC letter dated September 18, 2007 (ADAMS Accession No. ML072290132). This change was implemented within 30 days of receipt of the amendment.

Changes to the Final Safety Analysis Report (FSAR) will be made consistent with the description of the modifications and analyses described in this letter. No other changes to the plant licensing bases were identified.

4. RESPONSE INDEX FOR REQUESTED INFORMATION:

DNC received NRC letter dated February 9, 2006, requesting additional information (RAI) concerning the MPS3 response to GL 2004-02. Responses to the questions in the RAI are referenced by this section. Table 4-1 provides cross-reference to the section/content of this attachment that provides relevant information/answer(s).

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
1. Identify the name and bounding quantity of each insulation material generated by a large-break loss-of-coolant accident (LBLOCA). Include the amount of these materials transported to the containment pool. State any assumptions used to provide this response.	Section B: Debris Generation / ZOI (excluding coatings) Section H: Coatings Evaluation
2. Identify the amounts (i.e., surface area) of the following materials that are: (a) Submerged in the containment pool following a LOCA, (b) In the containment spray zone following a LOCA, (i) Aluminum (ii) Zinc (from galvanized steel and from inorganic zinc coatings) (iii) Copper (iv) Carbon steel not coated (v) Uncoated concrete Compare the amounts of these materials in the submerged and spray zones at your plant relative to the scaled amounts of these materials used in the Nuclear Regulatory Commission (NRC) nuclear industry jointly-sponsored Integrated Chemical Effects Tests (ICET) (e.g., 5x the amount of uncoated carbon steel assumed for the ICETs).	Section O: Chemical Effects
3. Identify the amount (surface area) and material (e.g., aluminum) for any scaffolding stored in containment. Indicate the amount, if any, which would be submerged in the containment pool following a LOCA. Clarify if scaffolding material was included in the response to Question 2.	Section O: Chemical Effects
4. Provide the type and amount of any metallic paints or non-stainless steel insulation jacketing (not included in the response to Question 2) that would be either submerged or subjected to containment spray.	Section O: Chemical Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
5. Provide the expected containment pool pH during the emergency core cooling system (ECCS) recirculation mission time following a LOCA at the beginning of the fuel cycle and at the end of the fuel cycle. Identify any key assumptions.	Section O: Chemical Effects
6. For the ICET environment that is the most similar to your plant conditions, compare the expected containment pool conditions to the ICET conditions for the following items: boron concentration, buffering agent concentration, and pH. Identify any other significant differences between the ICET environment and the expected plant-specific environment.	Section O: Chemical Effects
7. For a LBLOCA, provide the time until ECCS external recirculation initiation and the associated pool temperature and pool volume. Provide estimated pool temperature and pool volume 24 hours after a LBLOCA. Identify the assumptions used for these estimates.	Section F: Head Loss and Vortexing Section O: Chemical Effects
8. Discuss your overall strategy to evaluate potential chemical effects including demonstrating that, with chemical effects considered, there is sufficient net positive suction head (NPSH) margin available during the ECCS mission time. Provide an estimated date with milestones for the completion of all chemical effects evaluations.	Section O: Chemical Effects
9. Identify, if applicable, any plans to remove certain materials from the containment building and/or to make a change from the existing chemicals that buffer containment pool pH following a LOCA.	Section O: Chemical Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
10. If bench top testing is used to inform plant specific head loss testing, indicate how the bench top test parameters (e.g., buffering agent concentrations, pH, materials, etc.) compare to your plant conditions. Describe your plans for addressing uncertainties related to head loss from chemical effects including, but not limited to, use of chemical surrogates, scaling of sample size and test durations. Discuss how it will be determined that allowances made for chemical effects are conservative.	Section O: Chemical Effects
11. Provide a detailed description of any testing that has been or will be performed as part of a plant-specific chemical effects assessment. Identify the vendor, if applicable, that will be performing the testing. Identify the environment (e.g., borated water at pH 9, de-ionized water, tap water) and test temperature for any plant-specific head loss or transport tests. Discuss how any differences between these test environments and your plant containment pool conditions could affect the behavior of chemical surrogates. Discuss the criteria that will be used to demonstrate that chemical surrogates produced for testing (e.g., head loss, flume) behave in a similar manner physically and chemically as in the ICET environment and plant containment pool environment.	Section O: Chemical Effects DNC GL 2004-02 Extension of Corrective Actions Letter
12. For your plant-specific environment, provide the maximum projected head loss resulting from chemical effects (a) within the first day following a LOCA, and (b) during the entire ECCS recirculation mission time. If the response to this question will be based on testing that is either planned or in progress, provide an estimated date for providing this information to the NRC.	Section O: Chemical Effects DNC GL 2004-02 Extension of Corrective Actions Letter.
13. Not Applicable	-

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
14. Given the results from the ICET #3 tests (ADAMS Accession No. ML053040533) and NRC-sponsored head loss tests (Information Notice 2005-26 and Supplement 1), estimate the concentration of dissolved calcium that would exist in your containment pool from all containment sources (e.g., concrete and materials such as calcium silicate, Marinite^{TM}, mineral wool, kaylo) following a LBLOCA and discuss any ramifications related to the evaluation of chemical effects and downstream effects.	Section O: Chemical Effects
15. Not Applicable	-
16. Not Applicable	-
17. Not Applicable	-
18. Not Applicable	-
19. Not Applicable	-
20. Not Applicable	-
21. Not Applicable	-
22. Not Applicable	-
23. Not Applicable	-
24. Not Applicable	-
25. Describe how your coatings assessment was used to identify degraded qualified/acceptable coatings and determine the amount of debris that will result from these coatings. This should include how the assessment technique(s) demonstrates that qualified/acceptable coatings remain in compliance with plant licensing requirements for design basis accident (DBA) performance. If current examination techniques cannot demonstrate the coatings' ability to meet plant license requirements for DBA performance, licensees should describe an augmented testing and inspection program that provides assurance that the qualified/acceptable coatings continue to meet DBA performance requirements. Alternately, assume all containment coatings fail and describe the potential for this debris to transport to the sump.	Section H: Coatings Evaluation

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
26. Not Applicable	-
27. Not Applicable	-
28. Not Applicable	-
29. Your GL response indicates that you may pursue a reduction in the radius of the ZOI for coatings. Identify the radius of the coatings ZOI that will be used for your final analysis. In addition, provide the test methodology and data used to support your proposed ZOI. Provide justification regarding how the test conditions simulate or correlate to actual plant conditions and will ensure representative or conservative treatment in the amounts of coatings debris generated by the interaction of coatings and a two-phase jet. Identify all instances where the testing or specimens used deviated from actual plant conditions (i.e., irradiation of actual coatings vice samples, aging differences, etc.). Provide justifications regarding how these deviations are accounted for with the test demonstrating the proposed ZOI.	Section H: Coatings Evaluation
30. The NRC staff's safety evaluation (SE) on the NEI guidance report, NEI 04-07, addresses two distinct scenarios for formation of a fiber bed on the sump screen surface. For a thin bed case, the SE states that all coatings debris should be treated as particulate and assumes 100% transport to the sump screen. For the case in which no thin bed is formed, the staff's SE states that the coatings debris should be sized based on plant-specific analyses for debris generated from within the ZOI and from outside the ZOI, or that a default chip size equivalent to the area of the sump screen openings should be used (Section 3.4.3.6). Describe how your coatings debris characteristics are modeled to account for your plant-specific fiber bed (i.e., thin bed or no thin bed). If your analysis considers both a thin bed and a non-thin bed case, discuss the coatings debris characteristics assumed for each case. If your analysis deviates from the coatings debris characteristics described in the staff-	Section H: Coatings Evaluation

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
approved methodology, provide justification to support your assumptions.	
31. You indicated that you would be evaluating downstream effects in accordance with WCAP-16406-P. The NRC is currently involved in discussions with the Westinghouse Owner's Group (WOG) to address questions/concerns regarding this WCAP on a generic basis, and some of these discussions may resolve issues related to your particular station. The following issues have the potential for generic resolution; however, if a generic resolution cannot be obtained, plant-specific resolution will be required. As such, formal RAIs will not be issued on these topics at this time, but may be needed in the future. It is expected that your final evaluation response will specifically address those portions of the WCAP used, their applicability, and exceptions taken to the WCAP. For your information, topics under ongoing discussion include: (a) Wear rates of pump-wetted materials and the effect of wear on component operation (b) Settling of debris in low flow areas downstream of the strainer or credit for filtering leading to a change in fluid composition (c) Volume of debris injected into the reactor vessel and core region (d) Debris types and properties (e) Contribution of in-vessel velocity profile to the formation of a debris bed or clog (f) Fluid and metal component temperature impact (g) Gravitational and temperature gradients (h) Debris and boron precipitation effects (i) ECCS injection paths (j) Core bypass design features (k) Radiation and chemical considerations (l) Debris adhesion to solid surfaces (m) Thermodynamic properties of coolant	No Response Required Calculations in progress use the new Revision 1 to WCAP-16406, which is currently under NRC review.

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
32. Your response to GL 2004-02 question (d)(viii) indicated that an active strainer design will not be used, but does not mention any consideration of any other active approaches (i.e., backflushing). Was an active approach considered as a potential strategy or backup for addressing any issues?	Section J: Screen Modification Package
33. You stated that Microtherm insulation will be replaced, and that this replacement will reduce the postulated post-accident debris loading effects on the sump strainer. Please discuss the insulation material that will replace the Microtherm insulation including debris generation and characteristics parameters of the replacement insulation. Has the new insulation been evaluated in the debris generation, transport, head loss analyses and other sump design analyses?	Section B: Debris Generation/ ZOI (excluding coatings) Section C: Debris Characteristics Section O: Chemical Effects No replacement of Microtherm insulation is part of the resolution of GSI-191 at MPS3.
34. You stated that for materials for which no ZOI values were provided in the Nuclear Energy Institute (NEI) guidance report "Pressurized Water Reactor Sump Performance Evaluation Methodology," NEI 04-07, or the associated staff SE, conservative ZOI values are applied. Please provide a listing of the materials for which this ZOI approach was applied and the technical reasoning for concluding the value applied is conservative.	Section B: Debris Generation / ZOI (excluding coatings)
35. You did not provide information on the debris types and debris characteristics assumed in their evaluations other than to state the NEI and SE methodologies were applied. Please provide a listing of the debris types and a description of the debris characteristics assumed in these evaluations, and include a discussion of the technical justification for deviations from the SE-approved methodology.	Section B: Debris Generation / ZOI (excluding coatings) Section C: Debris Characteristics

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
36. Has debris settling upstream of the sump strainer (i.e., the near-field effect) been credited or will it be credited in testing used to support the sizing or analytical design basis of the proposed replacement strainers? In the case that settling was credited for either of these purposes, estimate the fraction of debris that settled and describe the analyses that were performed to correlate the scaled flow conditions and any surrogate debris in the test flume with the actual flow conditions and debris types in the plant's containment pool.	Section F: Head Loss and Vortexing
37. Are there any 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? In this case, dependent upon the containment pool height and strainer and sump geometries, the presence of the vent line or penetration could prevent a water seal over the entire strainer surface from ever forming; or else this seal could be lost once the head loss across the debris bed exceeds a certain criterion, such as the submergence depth of the vent line or penetration. According to Appendix A to Regulatory Guide 1.82, Revision 3, without a water seal across the entire strainer surface, the strainer should not be considered to be fully "submerged." Therefore, if applicable, explain what sump strainer failure criteria are being applied for the "vented sump" scenario described above.	Section J: Screen Modification Package
38. What is the basis for concluding that the refueling cavity drain(s) would not become blocked with debris? What are the potential types and characteristics of debris that could reach these drains? In particular, could large pieces of debris be blown into the upper containment by pipe breaks occurring in the lower containment, and subsequently drop into the cavity? In the case that large pieces of debris could reach the cavity, are trash racks or interceptors present to prevent drain blockage? In the case that partial/total blockage of	Section I: Upstream Effects

Table 4-1: Request for Additional Information Response Index

NRC Request for Additional Information Questions	Response
the drains might occur, do water holdup calculations used in the computation of NPSH margin account for the lost or held-up water resulting from debris blockage?	
39. What is the minimum strainer submergence during the postulated LOCA? At the time that the re-circulation starts, most of the strainer surface is expected to be clean, and the strainer surface close to the pump suction line may experience higher fluid flow than the rest of the strainer. Has any analysis been done to evaluate the possibility of vortex formation close to the pump suction line and possible air ingestion into the ECCS pumps? In addition, has any analysis or test been performed to evaluate the possible accumulation of buoyant debris on top of the strainer, which may cause the formation of an air flow path directly through the strainer surface and reduce the effectiveness of the strainer?	Section F: Head Loss and Vortexing
40. The September 2005 GL response stated that the licensee performed computational fluid dynamics analysis of which outputs included global (entire containment) and local (near sump pit) velocity contours, turbulent kinetic energy contours, path lines and flow distributions for various scenarios. Please explain how you used these outputs to determine the amount of debris that transports to the sump screen.	Section E: Debris Transport