VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

February 29, 2008

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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Serial No. 08-0019
NLOS/GDM R3
Docket Nos. 50-338/339
License Nos. NPF-4/7

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNITS 1 AND 2
SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION
DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

In a letter dated September 13, 2004, the NRC issued Generic Letter (GL) 2004-02, *Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors.* The purpose of the GL is to resolve NRC Generic Safety Issue (GSI) 191, *Assessment of Debris Accumulation on PWR Sump Performance*. The GL identified a potential susceptibility of recirculation flow paths and sump screens to debris blockage. Therefore, GL 2004-02 requested addressees to perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions in light of the information provided in the letter and, if appropriate, take additional actions to ensure system function. Additionally, addressees were requested to submit the information specified in the letter to the NRC.

Virginia Electric and Power Company (Dominion) submitted its response to GL 2004-02 in a letter dated March 4, 2005 (04-576), as supplemented by letter dated September 1, 2005 (Serial No. 05-212). In the September 1, 2005 letter, Dominion committed to completing corrective actions for North Anna Units 1 and 2 required by GL 2004-02 by December 31, 2007. In a letter dated February 9, 2006, the NRC forwarded a request for additional information (RAI) regarding Dominion's response to GL 2004-02. The NRC requested Dominion's response to the RAI within 60 days. However, in a subsequent letter dated March 28, 2006, as supplemented by a letter dated January 4, 2007, the NRC agreed to an alternative approach and timetable that allowed licensees to submit their responses to the RAIs no later than December 31, 2007 as part of their supplemental responses to the GL. In a letter dated November 30, 2007, the NRC extended the due date for supplemental responses to February 29, 2008.

This letter provides Dominion's supplemental response to GL 2004-02 for North Anna Power Station Units 1 and 2 and includes the necessary information to appropriately address the questions included in the NRC RAI noted above. By letter dated November 15, 2007 (Serial No. 07-0660), Dominion requested an extension of the

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completion date for certain GL 2004-02 corrective actions until November 30, 2008. By letter dated December 13, 2007, NRC granted an extension for North Anna to May 31, 2008. The corrective actions affected by the extension are noted in the applicable sections of the supplemental response.

In a letter dated August 15, 2007, revised by letter dated November 21, 2007, the NRC provided a content guide to the Nuclear Energy Institute (NEI) for responding to GL 2004-02. Dominion's supplemental response to GL 2004-02 considers the guidance included in the November 21, 2007 revised content guide and is provided in the enclosure.

In addition, North Anna Unit 2 was the subject of an NRC GSI 191 audit in July 2007. As a result of the audit, the NRC identified several open items that require resolution. A list of the open items and their resolution or status is provided in Attachment 1 of the supplemental response. Dominion's resolution of the items included in the NRC request for additional information (RAI) dated February 9, 2006 is provided in Attachment 2 of the supplemental response.

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

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 Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 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

Commitments: There are no new commitments contained in this letter.

Enclosure: Supplemental Response to Generic Letter 2004-02 – North Anna Power Station Units 1 and 2

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ENCLOSURE

SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)
NORTH ANNA POWER STATION UNITS 1 AND 2

GL 2004-02 Supplemental Response
North Anna Power Station (NAPS) Units 1 and 2

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GL 2004-02 SUPPLEMENTAL RESPONSE NORTH ANNA POWER STATION UNITS 1 AND 2

1.0 DESCRIPTION OF APPROACH FOR OVERALL COMPLIANCE

With the exceptions noted below, North Anna Power Station (NAPS) Units 1 and 2 have completed the corrective actions associated with Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors." Corrective actions to evaluate downstream and chemical effects are still in progress as permitted by the NRC in a letter dated December 13, 2007. In that letter, the NRC granted an extension to May 31, 2008, for North Anna to complete these remaining corrective actions. The corrective actions affected by the extension are noted in the applicable sections of the supplemental response.

There is reasonable assurance that the NAPS 1 and 2 Emergency Core Cooling System (ECCS) can provide long-term cooling of the reactor core following a loss of coolant accident (LOCA). The ECCS system 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 Containment Spray Systems (CSS) [i.e., the Quench Spray (QS) and Recirculation Spray (RS) systems] can operate to reduce the source term to meet the limits of 10 CFR 50.67 and remove heat from the containment.

The NRC performed an audit of NAPS 2 in July 2007 to verify that the implementation of Generic Safety Issue (GSI) 191 sump strainer and related modifications bring NAPS Unit 2 into full compliance with 10 CFR 50.46 and related requirements, and to draw conclusions as to the probable overall effectiveness of GL 2004-02 corrective actions. This supplemental response summarizes the NRC audit results and conclusions in the applicable sections of the supplemental response. Open items identified in the NRC audit are provided in Attachment 1 with the resolution status of each item. Dominion's resolution of the items included in the NRC request for additional information (RAI) dated February 9, 2006 is provided in Attachment 2.

<u>Methodology of Analyses</u>

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 NAPS 1 and 2. The evaluation considered 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 analyses (components) are currently being prepared consistent with WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI [Generic Safety Issue]-191," to identify any wear, blockage or vibration concerns with components and systems due to debris-laden fluids. The downstream effects analyses are currently being revised to incorporate new methodologies provided in WCAP-16406-P, Revision 1, August 2007.

Downstream effects analyses for the fuel and vessel are being prepared 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-top and reduced scale plant-specific testing.

Coatings are analyzed using a radius of 10-pipe diameters (10D) assigned to the Zone of Influence (ZOI) as detailed in Section 3.H for resolution of chemical effects and downstream effects.

2.0 GENERAL DESCRIPTION OF AND SCHEDULE FOR CORRECTIVE ACTIONS

The following modifications have been completed for NAPS Units 1 and 2 in support of GSI-191 resolution:

1. Two new containment sump strainers (with corrugated, perforated stainless steel fins) were installed with a total surface area of approximately 4400 ft^2 for the RS pumps in both units, approximately 2000 ft^2 for the Unit 1 LHSI pumps and approximately 1900 ft^2 for the Unit 2 LHSI pumps. These strainers replaced the previous containment sump screens, which had a surface area of approximately 168 ft^2.
2. Calcium-Silicate (Cal-Sil) insulation located within the steam generator (SG) cubicles and pressurizer room has been replaced with Paroc and Tempmat insulation in both Units 1 and 2.

3. Microtherm insulation has been removed from the NAPS Unit 2 containment. (No Microtherm insulation was installed in the Unit 1 containment.)
4. A drain was installed in the Primary Shield Wall to the Incore Sump Room (ISR) in NAPS Units 1 and 2 to reduce the water holdup volume and to increase the total volume of water available for recirculation.
5. Engineered Safety Features (ESF) circuitry was added to start the RS pumps on a Containment Depressurization Actuation (CDA) signal coincident with a Refueling Water Storage Tank (RWST) Level-Low signal. The Outside RS (ORS) pumps start immediately once the coincidence logic is satisfied. The Inside RS (IRS) pumps start following a time delay of 120 seconds once the coincidence logic is satisfied. These changes ensure sufficient water is available to meet the RS strainer submergence and RS pump net positive suction head (NPSH) requirements.
6. The RWST level instrumentation was modified to change the safety injection Recirculation Mode Transfer (RMT) setpoint from 19.4% to 16.0% RWST wide range level. This allows more energy to be removed from the containment and lowers the sump temperature prior to the LHSI pump suction switching from the RWST to the containment sump. This change also provides a higher water level in the containment sump prior to the LHSI pump suction switching to the containment sump. The combination of lower sump temperature and higher water level provides more NPSH to the LHSI pumps, and provides the required volume of water to maintain the strainers submerged.
7. The containment sump level transmitters were modified to protect them from clogging due to debris.
   - Level transmitters located within the sump have been modified by drilling holes through stilling wells at various places to prevent the element from clogging, and
   - Level transmitters located above the containment floor have been provided with debris shields to protect them from containment spray generated debris.

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

1. Completed debris generation and debris transport analyses. These analyses contain:
   a. Break selection criteria
   b. Calculation of amount and type of debris generated for limiting breaks
   c. Breakdown of debris sizes
   d. Physical debris characteristics (i.e. density, fiber size, particulate size)

   e. Calculation of amounts of each debris postulated to reach the ECCS strainer

2. Performed an analysis of clogging for components in ECCS and RS flow streams downstream of ECCS and RS strainers.
   a. Lists components susceptible to clogging which are in the ECCS and RS flowpaths downstream of the LHSI and RS strainers
   b. Demonstration of clogging potential

3. Evaluated Downstream Effects with regard to Fuel and Vessel which includes *(in progress):*
   a. Evaluation of fuel clad temperature response to blockage at the core inlet,
   b. Evaluation of fuel clad temperature response to local blockages or chemical precipitation on fuel clad surface, and
   c. Evaluation of chemical effects in the core region, including potential for plate-out on fuel cladding.

4. Completed analysis of water hold-up in containment to identify locations where water will be blocked from reaching the ECCS strainer. Water hold up includes:
   a. Holdup on component surface areas in containment
   b. Holdup on floors throughout containment
   c. Holdup of water in atmosphere

5. Revised the NAPS 1 and 2 Technical Specifications (TS) to support the installation of the new strainers and resolution of GSI-191 and NRC GL 2004-02. (ADAMS ML070720043)

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

7. Revised the LOCA Alternate Source Term (AST) analysis to include the effects from changing the RS pump start methodology and other changes identified in License Amendments 250 and 230 for NAPS Units 1 and 2, respectively, approved by the NRC on March 13, 2007 (ADAMS ML070720043).

8. Revised and/or created procedures and programs to ensure that future changes to the plant do not adversely affect the ability of the new containment strainers to perform their design function.

9. Trained operators on the operation of the RS and LHSI systems with respect to the new containment sump strainers.

The following actions are on-going, and updates will be provided in accordance with the extension request granted by the NRC in a letter dated December 13, 2007 that permitted completion of these actions by May 31, 2008.

1. Chemical and downstream effects testing evaluation.

2. Chemical effects bench top testing.

3. Chemical effects reduced scale testing.

4. Downstream wear evaluation for components.

5. Downstream wear evaluation for fuel and vessel.

3.0 SPECIFIC INFORMATION REGARDING METHODOLOGY FOR DEMONSTRATING COMPLIANCE

3a - Break Selection

The objective of the break selection process is to identify the break size and location that present the maximum debris loading for the design of the strainer.

To determine the limiting break location, Section 3.3.5 of NEI Guidance Report 04-07 requires the initial break locations to be moved at certain increments along the selected piping. However, the NRC review indicates that "for the purpose of identifying limiting break conditions, a more discreet approach driven by the comparisons of debris source term and transport potential can be effective at placing the postulated breaks." The latter approach was used at NAPS in determining the “Limiting Break” locations.

The largest diameter high-energy piping is the Reactor Coolant System (RCS) cold leg suction (intermediate leg) piping (31-inches ID) with the hot leg piping (29-inches ID) being somewhat smaller. The largest zones of influence (ZOI) would therefore be associated with the intermediate leg piping. In accordance with NEI 04-07 and the associated NRC Safety Evaluation (SE), small-bore piping was not evaluated.

Break locations in the Feedwater (FW) and Main Steam (MS) piping systems (secondary breaks) were not considered, as containment sump recirculation is not required for the mitigation of any FW or MS line breaks. Small bore (<2" diameter) piping breaks were also not evaluated, as they are not bounding as described in Section 3.3.4.1 of the NRC Safety Evaluation for NEI 04-07.

NAPS followed the methodology described in Sections 3.3 and 4.2.1 of NEI 04-07 and the associated SE, which provides the NRC-approved criteria to be considered in the overall break selection process for identifying the limiting break.

The NRC staff conducted an audit of the NAPS corrective actions to address GL 2004-02 and documented their findings in an audit report (ADAMS ML072740400). The audit report contains a detailed description of the break selection evaluation performed for NAPS. The NRC reviewed the break selection evaluation and found it to be consistent with the SE approved methodology and therefore acceptable.

The postulated break locations at NAPS are as follows:

- Break 1 (BK1) - The S/G B cold leg suction (intermediate leg) (31"-RC-5-2501 R-Q1) piping at the S/G nozzle at El. 257' [31" ID]
- Break 2 (BK2) - The S/G C cold leg suction (intermediate leg) (31"-RC-8-2501R-Q1) piping at the S/G nozzle at El. 257' [31" ID]
- Break 3 (BK3) - The S/G A cold leg suction (intermediate leg) (31"-RC-2-2501R-Q1) piping at the S/G nozzle at El. 257' [31" ID]
- Break 4 (BK4) - The pressurizer surge line (14"-RC-10-2501 R-Q1) at El. 264'-10" [14" OD]

3b - Debris Generation/Zone of Influence (ZOI) (excluding coatings)

The objective of the debris generation/zone of influence (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; and (2) the amount of debris generated by the break jet forces. NAPS followed the methodology described in Sections 3.4 and 4.2.2 of NEI 04-07 and the NRC SE, which provides the methodology to be considered in the ZOI and debris generation analytical process.

The destruction ZOI is defined as the volume about the break in which the jet pressure is greater than or equal to the destruction damage pressure of the insulation, coatings and other materials impacted by the break jet. The size of the ZOI is defined in terms of pipe diameters of the piping assumed to break. The ZOI is defined as a spherical volume centered at the assumed piping break.

The types of insulation used in the NAPS units that are within a potential ZOI include Transco RMI, Thermal Wrap low-density fiberglass insulation, TempMat high-density fiberglass insulation, and Paroc mineral wool. Dominion replaced the Cal-Sil and Microtherm particulate insulations with Paroc and TempMat insulation to eliminate the high head losses associated with the particulate insulation materials. The radii assumed by NAPS for insulation ZOI's are shown in Table 3b-1.

Table 3b-1, Zone of Influence (ZOI) Radius for Various Types of Insulation

Zones of Influence (ZOI)	
Insulation	ZOI Radius / Break Diameter (ft)
Transco Reflective Metal Insulation (RMI)	2.0
Transco Thermal Wrap Thermo-Lag TempMat with fiberglass cloth covering Fiberglass	17.0
TempMat with stainless steel mesh covering TempMat with silicone cloth covering	11.70
Calcium Silicate (jacketed) (Cal-Sil/asbestos, jacketed)	5.45
Paroc (mineral wool)	5.4

There is no information in either the NEI or NRC documents regarding the appropriate ZOI for some of the insulation materials installed at NAPS. The following is a description of the ZOI radius used for materials which did not have a specified ZOI.

The ZOI radius/break diameter ratio for Transco Thermal Wrap is assumed to be equal to unjacketed Nukon (17.0D). This is reasonable since both materials are considered low density fiberglass materials, and the ZOI for unjacketed Nukon is in the upper range of tested insulation materials.

The ZOI radius/break diameter ratio for fiberglass is assumed to be equal to unjacketed Nukon (17.0D). This is reasonable since both materials are considered low density fiberglass materials and the ZOI for unjacketed Nukon is in the upper range of tested insulation materials.

The ZOI radius/break diameter ratio for Tempmat insulation with fiberglass cloth covering is conservatively assumed to be equal to fiberglass (17.0D). This is reasonable since Tempmat is a more dense material than fiberglass and requires a higher destruction pressure.

The ZOI radius/break diameter ratio for Tempmat with silicone cloth covering is assumed to have the same ZOI as Tempmat with stainless steel wire retainer

(11.7D). The ZOI for Tempmat with stainless steel wire retainer is determined in the NRC Safety Evaluation to NEI 04-07.

The ZOI radius/break diameter ratio for mineral wool (Paroc) insulation is assumed to be 5.4D. This is based on its similarity to K-wool insulation.

Table 3b-2 lists the debris load for the limiting break locations at NAPS.

Table 3b-2, Bounding LOCA-Generation Insulation Debris Quantities*

Debris Type	Break BK1	Break BK2	Break BK3	Break BK4
ZOI Generated				
Metallic (ft^2)				
Transco RMI	710.21	732.77	751.57	1306.32
Fibrous (ft^3)				
Thermal-Wrap	641.88	646.43	648.14	0
Temp-Mat	1.45	15.82	1.63	1.73
Paroc Mineral Wool	62.48	57.12	77.75	107.82
Containment Spray or Submergence Generated				
Fibrous (ft^3)				
Fiberglass	4.2	4.2	4.2	4.2
Thermal-Wrap	0	0.79	0.79	0.79
Temp-Mat	1.91	2.33	2.46	2.86
Total Fibrous Debris				
Fibrous (ft^3)	711.92	726.69	734.97	117.43
* 5% Margin was conservatively included in all debris quantities. Coatings are not included in the table.				

The NRC staff audit report contains a detailed description of debris generation and the zones of influence specific to NAPS. The NRC reviewed the debris generation and zone of influence methodology used for NAPS and found it acceptable.

3c. - 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 NAPS containment include debris from four types of insulation: Paroc, Transco Thermal Wrap, TempMat and Transco RMI. Besides the insulation sources, other potential debris sources include latent fiber, latent particulate, foreign material debris, and coatings debris.

The analyzed debris loading for NAPS includes RMI, qualified coatings, unqualified coatings, latent particulate debris, latent fibrous debris, fibrous insulation debris, and foreign materials such as tape, tags, glass, and stickers. Latent debris characteristics are discussed in Section 3d, and coatings debris characteristics are discussed in Section 3h.

Reflective Metal Insulation

The RMI installed at NAPS is Transco Mirror Insulation constructed of stainless steel foils with three layers per inch of thickness. The size distribution assumed for the RMI debris at NAPS is 75% small fines and 25% large pieces. This distribution is consistent with the guidance in NEI 04-07 and Table 3-3 of the NRC staff's SE on NEI 04-07.

Fibrous Insulation

The fibrous insulation within the NAPS ZOIs is Transco Thermal-Wrap, Paroc, Temp Mat, and latent fibers. The Paroc is a mineral wool type insulation similar to Kaowool.

The debris characteristics NAPS assumed for the fibrous material were consistent with the NEI guidance and the NRC SE.

The size distribution for Transco Thermal-Wrap, Paroc, and Temp Mat is shown in Table 3c-1.

Table 3c-1, Debris Size Distribution

Debris Type	Category	Category Percent
Transco Thermal-Wrap Fiber	Small Fines	8%
	Small Pieces	25%
	Large Pieces	32%
	Intact	35%
Paroc	Small Fines	100%
TempMat	Small Fines	60%
	Intact	40%

The NRC audit report contains a detailed description of debris characteristics specific to NAPS. The NRC reviewed the debris characteristics for NAPS and found it acceptable.

3d - Latent Debris

NAPS performed an evaluation of the potential sources of latent debris, using guidance provided by the NEI 04-07 and the NRC Safety Evaluation Report.

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. NAPS followed NEI 04-07 recommendations for quantifying the mass and characteristics of latent debris inside containment.

Latent Fibrous Debris

NAPS assumed that latent fiber comprises 15% (by mass) of the total latent debris loading measured in the containment. NAPS assumed that latent fibrous debris is composed of 100% small fines. Transco Thermal-Wrap fibers were used for the latent fibrous debris during testing.

The properties NAPS assumed for latent fibrous debris are consistent with NUREG/CR-6877 and the NRC SE on NEI 04-07.

Latent Particulate Debris

NAPS assumed that particulate material comprises 85% (by mass) of the total latent debris loading measured in the containment. NAPS assumed that latent particulate debris is composed of 100% fine particulate. Walnut shell flour was used as the surrogate for latent particulate debris.

Estimate of Latent Debris Mass

The surface areas within containment that are available for accumulation of latent debris were identified, and eight surface-area categories were defined. After accounting separately for horizontal and vertical surface configurations, a total of twelve area types were defined. The surface area of each of the twelve area types was computed with the aid of plant drawings. The individual area contributions were tabulated in the debris generation calculation.

To estimate the latent debris mass, including dust, particulate and lint, NAPS took samples. Samples were taken for each of twelve area types. The sample locations are identified in the latent debris walkdown report.

For each of the twelve area types, the measured sample masses and the surface area sampled were used to compute the mean sample mass per unit area, the standard deviation of this quantity, and the 90% confidence limit of the quantity.

The 90% confidence limit was conservatively used as the representative latent debris sample mass per unit area for each specific area type sampled.

The total mass of latent debris present in containment in each of the twelve area types was extrapolated from the measured debris masses by multiplying the computed sample mass per unit area by the estimated surface area in containment associated with the specific area type. The masses identified with each area type were summed to provide the total latent debris in containment.

The NRC staff audit report contains a detailed description of latent debris for NAPS. The NRC reviewed the method used for quantifying latent debris at NAPS and found it acceptable.

3e - Debris Transport

The debris transport analysis estimates the fraction of debris generated by a LOCA or other high-energy line break requiring containment sump recirculation that would be transported to the sump suction strainers. Generally speaking, debris transport in the containment would occur through four major mechanisms:

- Blowdown transport, which is the vertical and horizontal transport of debris throughout containment by the break jet
- Washdown transport, which is the downward transport of debris due to fluid flows from containment sprays and the pipe rupture
- Pool-fill transport, which is 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 (not involved in recirculation flow) during sump recirculation
- Containment pool recirculation transport, which is 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 containment spray systems 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 which 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 on the containment floor.

NAPS did not credit a computational fluid dynamics (CFD) analysis to calculate the flow of water in the containment pool during the recirculation phase of a LOCA as an input to the determination of debris transport fraction.

NAPS considered it conservative to use the maximum velocity flow path in the containment pool in determining the fraction of LOCA-generated debris that would reach the sump strainers. Specifically, NAPS methodology was to compare the maximum velocity flow path in the containment pool to the metrics for incipient tumbling and "lifting over a curb" velocities. This methodology is considered to be conservative, since a significant fraction of the debris in containment would likely not be exposed to such high velocities.

Without a CFD calculation or other analysis of the flow velocities in the containment pool, NAPS assumed for all four analyzed breaks that the maximum pool flow velocity would be greater than 0.28 ft/s (which is the highest transport velocity used in the debris transport calculation).

The transport methodology used for NAPS is based on the methodology in NEI 04-07, as modified by the associated NRC SE, and Regulatory Guide 1.82. In particular, NAPS methodology for calculating debris transport fractions was modeled on the NEI 04-07 baseline methodology.

The NRC staff audit report also contains a detailed description of debris transport for NAPS. The NRC reviewed the methodology used for quantifying latent debris at NAPS and found it acceptable.

3f - Head Loss and Vortexing

Head loss and the potential for vortexing were determined during head loss testing conducted at AECL facilities in Chalk River, Ontario, Canada.

The ECCS and containment spray systems that support containment depressurization during a postulated event are the Quench Spray (QS) system, RS system and the ECCS. These systems are depicted in Figures 3f-1 through 3f-3.

There are three main design concerns that set limits on the maximum allowable strainer head loss:

- LHSI and RS pump NPSH margin (see Section 3g),
- Flashing within and downstream of strainers, and
- Air dissolution within the strainer and voiding at pump inlets and the effect on required NPSH.

Head loss was determined analytically using the correlations in NUREG/CR-6224 and NUREG/CR-6808. AECL then performed prototypical head loss testing based on the selected strainer surface area and the calculated debris loading. The data from these tests were used to determine the head loss across the strainer surface.

From the pump NPSH analysis, the allowable design head loss across the new RS strainer is 5.0 feet at 180°F and at a flow rate of 12,620 gpm, which corresponds to the maximum flow for all four RS pumps operating. From the pump NPSH analysis, the allowable design head loss across the new LHSI strainer is 8.5 feet at 113°F and at a flow rate of 4,050 gpm, which corresponds to the maximum flow for single-pump operation. For the LHSI system, Dominion determined that single-pump operation is the most critical mode of operation from an NPSH margin perspective, due to the higher flow rate through an individual pump during single pump operation. AECL conducted prototypical head loss testing to qualify its design; however, these tests did not account for potential chemical effects precipitates. Testing for chemical effects will be described in a later response (see Section 3o). As part of the prototypical head loss testing program, Dominion evaluated the susceptibility of the strainers to vortex formation.

The NAPS audit report, Section 3.6, contains a detailed description of head loss and vortexing for NAPS. The NRC staff reviewed the methods used for determining head loss and testing for vortex formation for the NAPS strainer. With the exception of the issues identified in Open Item 3.6-1, Temperature Scaling of Head Loss Test Data, and Open Item 3.6-2, Justification for Time-Dependent Head Loss Assumptions (see Attachment 1), the NRC staff found these methods acceptable.

Resolution of NRC Audit Open Item 3.6-1

Appendix I of the NRC audit states:

> **Open Item 3.6-1 (Page 43):** Temperature Scaling of Head Loss Test Data
>
> The licensee scaled test head losses to plant sump conditions based only on temperature-driven viscosity variations. Test phenomena driven by differential

pressure (e.g., opening of paths through the bed) should be considered as well. The licensee should evaluate this issue and provide a summary of the method and results to the staff in its supplemental response to GL 2004-02 due by the end of December 2007.

Dominion Response

As noted, test results have been scaled to the slightly-higher specified sump temperature corresponding to the allowable head loss using the ratio of viscosities at the two temperatures. This is acceptable for the following reasons:

- Flow through the debris bed is laminar and, therefore, head loss is proportional to viscosity.
- Governing head losses came from the thin bed tests. In all cases, the peak loss at any time during the test was considered as the final test result.
- No sudden decreases in debris head loss were observed during qualification tests.
- No degradation of the bed (e.g., due to bore holes) was observed visually during or after any test.
- Gradual decreases in head loss over 8 to 48 hours were observed during Tests NA-15 and NA-16 (LHSI thin bed head loss tests); however, these occurred during the bed formation process before a thin bed had fully formed.
    - With two nominal 1/16-inch fiber additions, and roughly 30% of the fibrous debris settling on the floor, the theoretical bed thickness was only about 0.088 in., much less than the thickness required for a stable thin bed (shown in this and previous test programs to be approximately twice as thick as this). Tests NA-15 and NA-16 both show a gradually decreasing head loss before the third addition of fiber, then a quick increase right after the third addition. The partially-formed bed (i.e., a bed of less thickness than the stable thin bed) is too fragile to be stable and, therefore, slowly breaks down. However, when additional debris is added, it preferentially deposits in the most porous spots, which quickly become plugged. Truly stable behavior is only reached once the true thin bed thickness is reached. At this point, further debris additions do not cause sharp changes in head loss. This typically occurs after the fourth debris addition.
- In addition, there is conservatism in scaling from test temperatures to higher specified sump temperatures. The debris bed will expand slightly when head loss is lower, i.e., at the higher sump temperature, the bed would be expected to be slightly more porous than at the lower test temperature. The assumption of a purely linear relationship between head loss and viscosity when scaling to higher temperatures is, therefore, conservative.

Resolution of NRC Audit Open Item 3.6-2

Appendix I of the NRC audit states:

> **Open Item 3.6-2 (Page 44):** Justification for Time-Dependent Head Loss Assumptions
>
> The licensee assumed that at the beginning of low head safety injection operation in the recirculation mode there would be no debris accumulation on the low head safety injection strainer, and that the strainer head loss due to debris would reach the peak thin bed head loss after a period of time. The licensee should provide the basis for these assumptions in its supplemental response to GL 2004-02.

Dominion Response

Review of thin bed test results shows that the thin bed debris bed development does not build as fast as NPSH margin increases for the LHSI pumps following RMT.

Comparison of results from tests NA-15 and NA-16, the two LHSI strainer thin bed qualification tests, revealed that the maximum one-minute rate of rise, 0.013 psi/minute, during thin bed development (the period following the first and second fiber additions) occurred in test NA-16. (Maximum rate in NA-15 was 0.009 psi/minute.)

For comparison to minimum NPSH margin vs. time, clean strainer head loss (0.97 ft.) was added to three times (0.04 psi/minute) the observed maximum rate of rise. Strainer head loss increase was assumed to begin at RMT and be sustained until the maximum observed peak head loss was achieved. This comparison is shown in Figure 3f-4. The LHSI NPSH margin after RMT increases significantly faster than the maximum LHSI strainer debris head loss, as can be seen in Figure 3f-4. The conservatisms in this analysis are:

- A conservative fiber debris load is utilized in testing in that all fibers are added as fines, including that which is assumed to be long-term eroded from small and large pieces.
- The LHSI strainer is elevated; thus, fibrous debris would be less likely to approach.
- LHSI clean strainer head loss of 0.97 ft. for NAPS Unit 1 was utilized as conservative compared to LHSI clean strainer head loss of 0.74 ft. for NAPS Unit 2.
- The most limiting LHSI NPSH margin vs. time curve from the containment analysis is utilized for the comparison.

- For the limiting LHSI NPSH margin case, the RS strainer would be operating for approximately 27 minutes prior to RMT for the LHSI pumps, thus a significant portion of the suspended debris would be drawn to the RS strainer.
- Three times (0.04 psi/minute) the maximum observed rate of head loss increase in any one-minute period (0.013 psi/minute) is utilized for the comparison. The maximum increase over any ten minute period was 0.020 psid. Review of figure 3f-4 shows that up to thirteen times (0.17 psi/minute) the maximum rate of rise can be tolerated and not exceed NPSH margin.
- Maximum rate of rise is assumed to begin at RMT and sustained during the entire head loss increase. Review of test results shows that a significant amount of time (tens of hours) is needed to develop a significant head loss and that increase is not linear.
- Rate of rise is not reduced for change in water viscosity from test temperature (104°F) to calculated sump temperature (up to 170°F at RMT).
- Water density at 212°F used for conversion of psi to feet of water (2.408 ft/psi). This maximizes the numerical value of feet of water in the comparison.
- In test NA-16, approximately 62 hours elapsed prior to test head loss reaching 1 psid. Figure 3f-4 shows at an assumed rate of 0.04 psi/minute that 1.4 psid is reached in 35 minutes.

Strainer Flashing

Subsequent to the NAPS audit, the performance of the replacement strainer system was analyzed for the possibility of liquid flashing into vapor. The onset of flashing is defined as the point at which the static pressure at a juncture in the system decreases to a level that equals the saturation pressure of the water at that juncture.

The analysis considered the following input parameters: (i) containment pressure, (ii) water level above the top of the RS fins, (iii) bulk water temperature, and (iv) IRS pump suction temperature (cooler than bulk water). The static pressure at each juncture of the strainer system was calculated by considering the calculated values of non-recoverable head losses and dynamic head as determined for RS 4-pump operation.

The analysis revealed that the onset of flashing would occur when the debris bed on the fins reached a pressure loss of 1.6 ft. or about 70% of the full-debris pressure loss of 2.28 ft. at the sump water temperature used in the flashing analysis. If the pressure loss of the debris bed increases above this level, then flashing of the liquid into vapor is expected to start occurring at this location.

The condition for which the possibility of flashing was evaluated is a worst-case low-margin scenario approximately 5 to 10 minutes after the re-circulation spray system is put in service. At this time a debris bed is only just beginning to form on the strainer fins. Testing performed by AECL has shown that several hours to days are required for the full debris bed to form and to reach the point where maximum debris pressure loss occurs. At the time the transient low margin condition occurs the pressure loss due to debris will be well below 70% of the full debris pressure loss and flashing will not occur within the strainer. The test results are applicable to the installed strainer at North Anna, as the test arrangement is representative of a segment of the full strainer, and the strainer is designed to operate uniformly over the whole surface area (using tuned flow-orifices).

No flashing analysis for the LHSI strainer is needed because the margin to flashing is greater than 12 ft when LHSI strainer becomes operational. The non-recoverable head loss for the debris laden LHSI strainer is 3.9 ft, leaving 8.1 ft of margin available for dynamic head losses. The maximum dynamic head loss for the LHSI strainer is 1 ft, which leaves 7.1 ft of margin to saturation.

In the case of clean fins, the minimum margin to flashing for the RS system is 1.56 ft. This number is arrived at by taking the difference between the debris-loss to achieve zero margin and the clean-fin pressure loss.

<u>Strainer Air Dissolution</u>

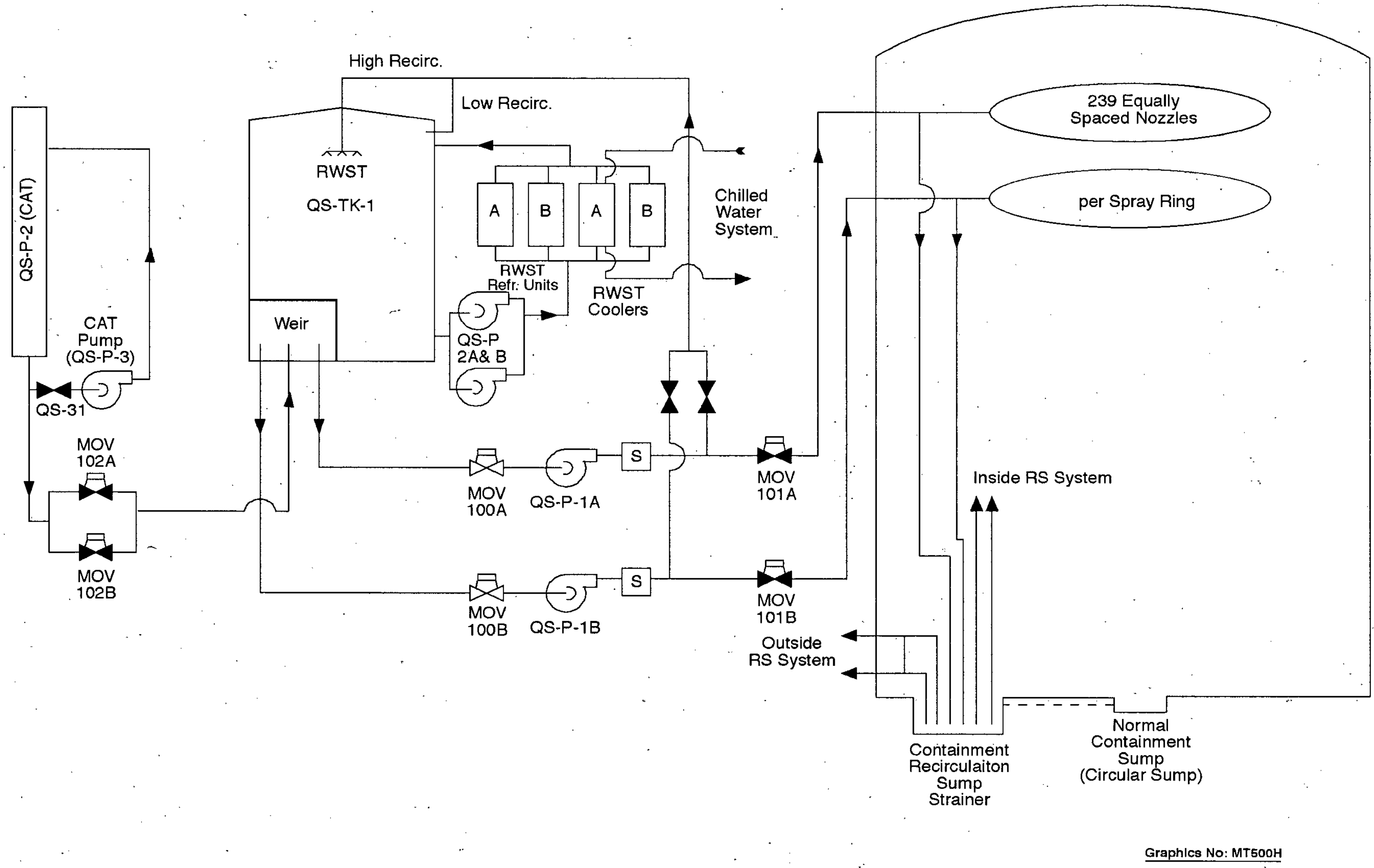
Per Attachment V-1 to Appendix V of the SE and Regulatory Guide 1.82, the design of PWR recirculation sumps also needs to consider air evolution (release from solution) and air ingestion (i.e., due to vortex formation). Per Attachment V-1 to Appendix V of the SE, the inlet void fraction (total percentage of air and water vapor by volume) downstream of the screen should be limited to 3% to prevent cavitation problems with the ECCS/CSS pumps. Per Regulatory Guide 1.82, the amount of air ingestion should be limited to 2% to prevent degraded performance of the ECCS/CSS 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%.

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.

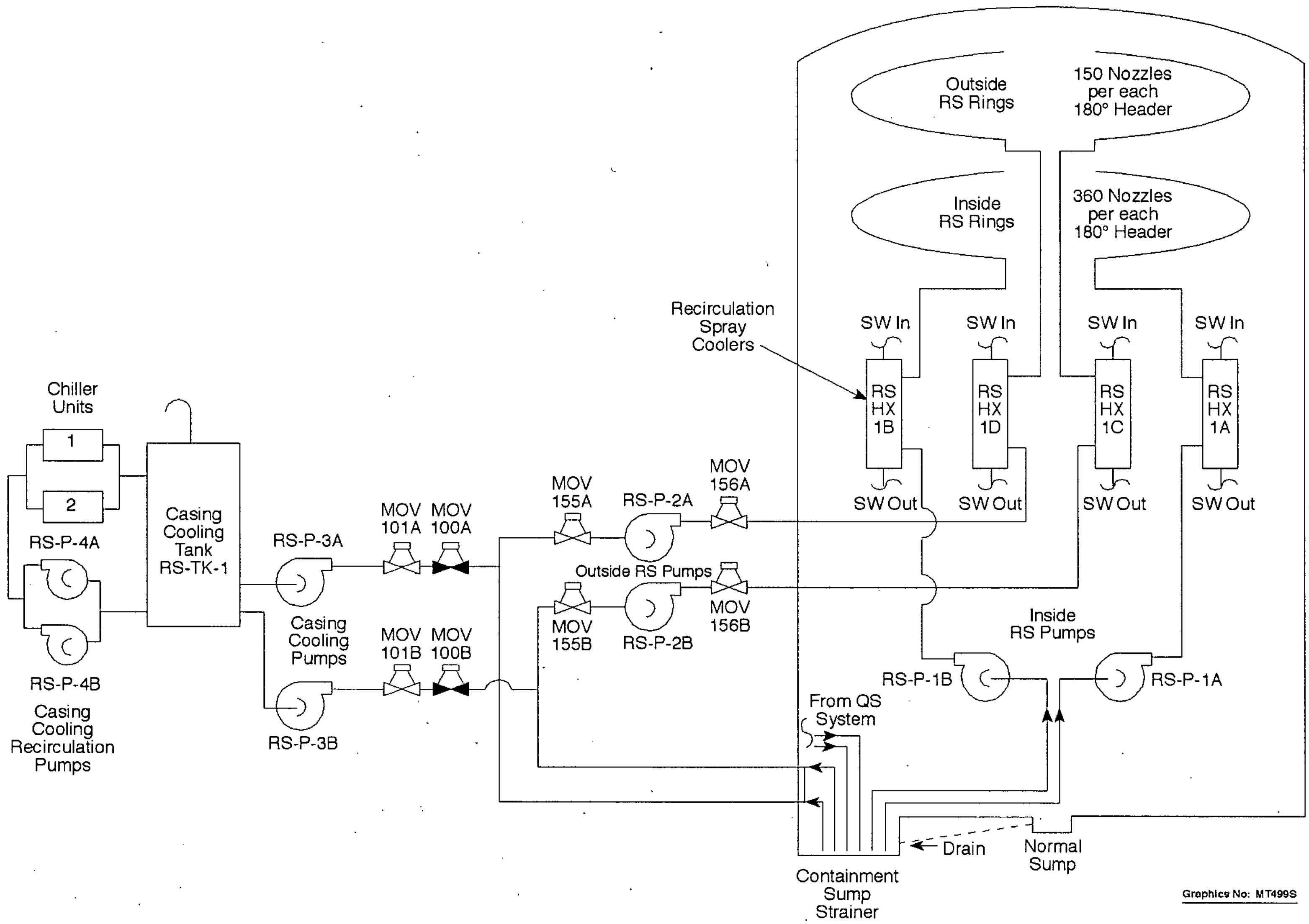
The analytical evaluation for the maximum RS strainer head loss from testing demonstrates that the maximum void fraction at the RS strainer exit to the pump suction piping is 0.18%. This is for the long-term containment conditions after a LOCA with sump temperature of 100°F and RS pump NPSH available of at least 25.3 ft. The void fraction is significantly less than 2%. In accordance with Attachment V-1 to Appendix V of the SE, the NPSH required would be increased by a multiplier $\beta = 1 + 0.50\alpha_p$, where α_p is the air ingestion rate (in percent by volume). The multiplier of 1.09 (1 + 0.50*0.18%) would increase the NPSH required values from Table 3g-1 by about 1 ft to 10.5 ft for the IRS pumps and 12.3 ft for the ORS pumps. The long-term RS pump NPSH margin is 6.5 ft (25.3 ft NPSH available minus 12.3 ft NPSH required for the ORS pumps minus 6.5 ft total strainer head loss) with a void fraction of 0.18%.

For the LHSI strainer, the maximum head loss for the full-debris laden strainer was 3.9 ft at 113°F while the minimum depth of water to the sump well is 6.8 ft. The highest dynamic pressure in the system is 1.01 ft at 113°F. Hence, the water depth above the floor exceeds the head loss and dynamic head by a margin of 1.89 ft. There is no voiding exiting the LHSI strainer. The air dissolution analysis for the LHSI strainer establishes a maximum head loss of 5.79 ft (3.9 ft + 1.89 ft), which is more limiting than the 8.5 ft from the LHSI pump NPSH analysis.



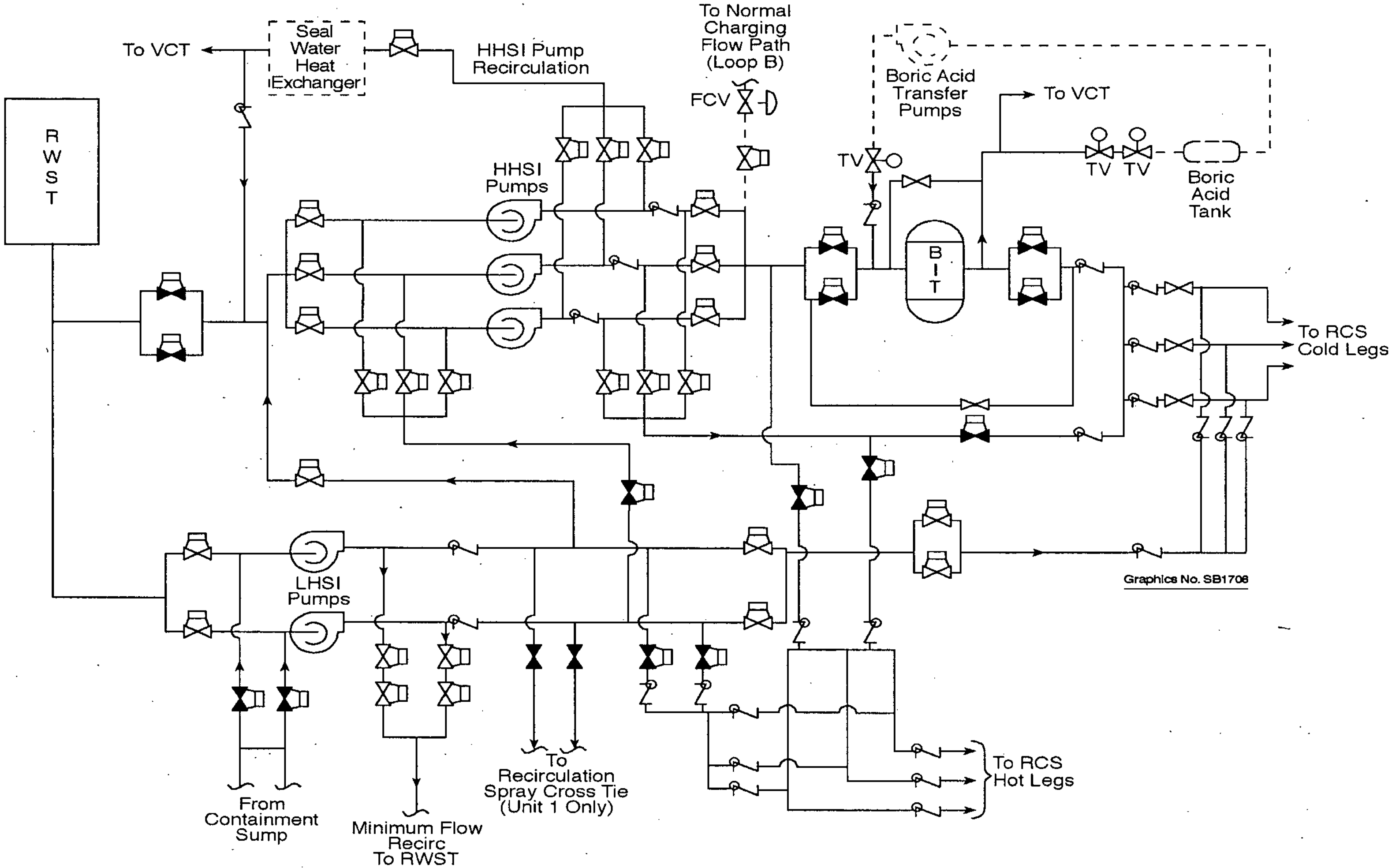
QUENCH SPRAY SYSTEM (NORTH ANNA)

Figure 3f-1



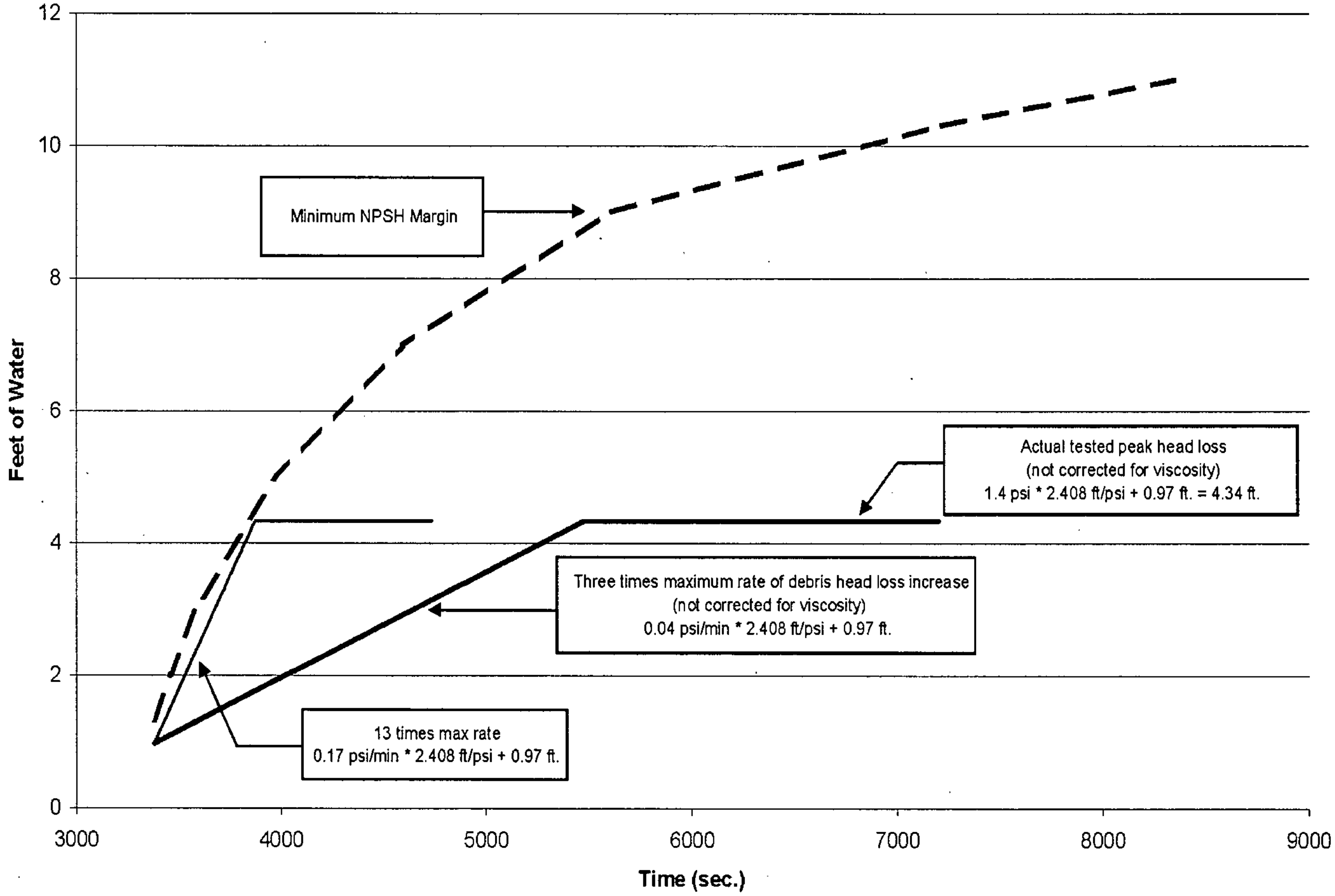
RECIRCULATION SPRAY SYSTEM (NORTH ANNA)

Figure 3f-2



EMERGENCY CORE COOLING SYSTEM (NORTH ANNA)

Figure 3f-3



LHSI NPSH MARGIN AND TESTED DEBRIS HEAD LOSS

Figure 3f-4

3g - Net Positive Suction Head (NPSH)

A transient calculation of NPSH available (NPSHa) has been performed for the LHSI, ORS and IRS pumps for NAPS Units 1 and 2 using the GOTHIC analysis methodology in topical report DOM-NAF-3-0.0-P-A. The NAPS GOTHIC analyses are described in Dominion letter dated October 3, 2006 (Serial No. 06-849) that included Technical Specification changes and License Amendments for resolution of GSI-191. The GOTHIC analyses included the described changes that would reflect the North Anna configuration after the Technical Specification changes and associated plant changes (e.g., start RS pumps on RWST Level Low coincident with a CDA signal) are implemented. Because the replacement sump strainer hydraulic design was not complete when the GOTHIC analyses were performed, the replacement strainer head loss was not included in the GOTHIC model (the original sump screen head loss was included). Thus, the difference between the GOTHIC NPSHa result and pump NPSH required represents the margin available for the replacement strainer head loss (clean and debris bed).

Table 3g-1 summarizes the current NPSHa results from GOTHIC with the margin to NPSH required. The NPSHa results vary from those reviewed by the NRC and documented in the NAPS audit report (ADAMS ML072740400) for four reasons:

1) The original analyses had included a friction head loss for the original containment sump screens that is no longer required. The 0.2 ft head loss for the LHSI pump at 4050 gpm was deducted from the 8.8 ft suction friction loss. This adjustment was not made to the RS pump margins.
2) The GOTHIC models were revised to correct an error in the containment water level versus volume table that was over-predicting NPSHa by about 0.6 ft. This issue was identified during the NRC audit in July 2007 as open item 3.7-1. The resolution of the audit item is provided later in this section.
3) The minimum safety analysis flow rates for the IRS and ORS pumps were reduced in August 2007 to generate pump test margin and accommodate the new strainer head loss. This analysis change reduced the LHSI pump minimum NPSHa by 0.2 ft due to the reduced sump cooling before recirculation mode transfer.
4) The GOTHIC models were rerun to address the above items with version 7.2a. This code version includes a correction to the interfacial heat and mass transfer model that had been under-predicting the heat transfer between the containment pool and the atmosphere. Version 7.2a provides a small increase in LHSI pump NPSHa and no change to NPSHa for the RS pumps.

Table 3g-1: Summary of GOTHIC NPSH Analysis Results

Pump	Minimum NPSHa*	Time of Minimum NPSHa	NPSH Required at Maximum Flow	Minimum NPSH Margin*
LHSI	14.7 ft	3383 seconds (transfer to recirculation mode)	13.4 ft at 4050 gpm	1.3 ft
IRS	14.6 ft	2084 seconds (8 minutes after pump start)	9.6 ft at 3400 gpm	5.0 ft
ORS	18.0 ft	1524 seconds (8 minutes after pump start	11.3 ft at 3750 gpm	6.7 ft

* NPSHa increases significantly after the minimum point as sump temperature decreases and water level increases until the RWST and casing cooling tanks are injected fully. Refer to Dominion letter dated October 3, 2006 (Serial No. 06-849) or the North Anna UFSAR for figures of transient NPSHa and containment conditions (pressure, liquid temperature and water level).

Resolution of NRC Audit Open Item 3.7-1

Section 3.7.4 of the NAPS audit report (ADAMS ML072740400) states:

"NAPS implemented an NPSHa formulation in the GOTHIC code to compute NPSHa. This formulation of the NPSHa equation is different than the standard equation that is referenced in the licensee's Updated Final Safety Analysis Report. The staff found that there is an inconsistency in the results provided by these two different formulations, and that there is a non-conservative bias in the NPSH margin values the licensee calculated using the GOTHIC code that are reported in Table 12. This issue was identified as Open Item 3.7-1."

Appendix I of the NAPS audit report (ADAMS ML072740400) states:

Open Item 3.7-1: Net Positive Suction Head Available Calculation.

The calculated net positive suction head available margins for the low head safety injection, inside recirculation spray and outside recirculation spray pumps were non-conservative. The margins for these pumps were overestimated by approximately 0.6 feet of head because of an error in the calculation of the static head of liquid. The licensee should evaluate this issue and provide a summary of the method and results to the staff in its supplemental response to GL 2004-02.

Dominion Response

The NPSHa formulation in GOTHIC is specified by Equation 16 in topical report DOM-NAF-3-0.0-P-A. The GOTHIC formulation is consistent with the standard equation in the NAPS UFSAR, was validated during benchmarking analysis to the previous containment analysis of record, and provides an accurate calculation of NPSHa when the inputs are correctly applied in the model. Thus, Dominion considers the GOTHIC formulation to be acceptable. The non-conservative bias in NPSHa was introduced into the calculation when attempting to reduce the containment water level for holdup.

GOTHIC calculates the pump suction pressure based on the GOTHIC water level in containment, which is based on all of the liquid volume being deposited in an open cylinder of nominal diameter (126 ft). To calculate NPSHa at the pump impeller centerline, the GOTHIC pump suction pressure needs to be adjusted to account for the actual water level in the containment basement when considering equipment and structure blockages and holdup of liquid volume at higher elevations. The GOTHIC model correctly calculated a reduced liquid volume based on holdup, but the water level versus volume table was incorrectly implemented. As a result, the NPSHa analysis used a water level that was based on the total containment liquid volume instead of the reduced liquid volume adjusted for holdup. This explains the consistent bias of approximately 0.6 ft in each GOTHIC case. In conclusion, the non-conservative bias in NPSHa was tracked to an error in the implementation of the containment water level versus volume relationship and not to the GOTHIC formulation for calculating NPSHa.

To resolve the issue, the GOTHIC models for NPSHa were modified to use the containment liquid volume reduced for holdup in determining the basement water level. Further, the GOTHIC analysis calculation was revised to report each input to the NPSHa calculation at the time of minimum NPSHa so that a hand calculation can verify that the UFSAR standard formulation is satisfied. Table 3g-1 above reflects the NPSHa analysis results with the four analysis changes identified above.

3h - Coatings Evaluation

The NAPS audit report (ADAMS ML072740400) contains a detailed description and evaluation of coatings for NAPS and should be referenced for information on Dominion's coating evaluation. It should be noted that the radius of the coating ZOI used in the analysis for NAPS was 5.0D. The test methodology and data used to support a 5.0D ZOI was based on Westinghouse document WCAP-16568-P. The staff reviewed the coatings guidance in WCAP-16568-P and concluded that the 5.0D ZOI was appropriate.

However, subsequent to the issue of the NAPS audit report, and upon further review of WCAP-16568-P, it was determined that a 10D ZOI is more appropriate because Dominion believes that the WCAP did not adequately address the Dupont coatings applied at NAPS.

The total Qualified, and Unqualified/Damaged coating debris for a 10D ZOI has since been determined to be 9.92 ft^3.

The total debris load calculated from DBA Qualified coatings on steel and concrete, and Unqualified/Damaged coatings using a 10D ZOI are within the new strainer design basis. Coating program documents have been changed to reflect the ZOI dry film thickness limitation for maintenance coating.

3i - Debris Source Term

Section 5.1 of NEI 04-07 and the NRC staff's accompanying SE discuss five categories of design and operational refinements associated with the debris source term considered in the sump performance analysis.

The five categories considered are:

1. housekeeping and foreign material exclusion programs
2. change-out of insulation
3. modification of existing insulation
4. modification of other equipment or systems
5. modification or improvement of coatings program

The NRC staff audit report for NAPS contains a detailed description of the programmatic controls which were reviewed by the NRC and found it acceptable. One exception was identified as Open Item 5.4-1, Evaluate Chemical Effects (see Attachment 1), that relates to the possibility of a thin bed when chemical participants are considered. Chemical effects testing is still ongoing, and the results of this testing will be provided at a later date, at which time Open Item 5.4-1 will be addressed.

3j - Screen Modification

The former containment sump configuration consisted of a platform and trash rack that enclosed the sump area. The former screens consisted of gratings that acted as a trash screen for large debris (and vortex suppressants) and three stages of mesh screening which prevented particles larger than the smallest nozzle orifice of the RS rings from entering the RS pump suction. The former strainers had a surface area of approximately 168 ft^2 each.

Two new separate strainer assemblies have been designed to handle the RS and LHSI system requirements. The new design has independent strainers for the RS and LHSI systems with the LHSI strainer mounted on top of the RS strainer. The RS strainer assembly is designed to be mounted on the containment floor in and around the containment sump. Each strainer module contains a number of fins attached to the body of the module. Each RS module is bolted to the containment floor and connected to other modules by flexible metal seals.

The new design does not include features that further separate the strainers for opposite pumps within the same system. The redundancy in the strainer design is not required since the strainers are capable of withstanding the force of full debris loading, in conjunction with design basis conditions, and seismic activity. As such, implementation of the new strainers does not have the potential of physical failure.

The replacement containment sump strainer is a finned strainer manufactured by AECL. It has a surface area of approximately 4400 ft^2 for the RS pumps in both units, approximately 2000 ft^2 for the Unit 1 LHSI pumps and approximately 1900 ft^2 for the Unit 2 LHSI pumps, and is fully submerged at the start of recirculation. The difference in surface area between the Unit 1 and Unit 2 LHSI strainers is due to the fin configurations needed to clear interferences.

The new strainer is composed of a solid housing which surrounds the ECCS suction pipes and from which protrude two solid rectangular headers: one header for the RS pumps and one header for the LHSI pumps. 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 0.0625 inches. Each of the fins is nominally 6 inches apart (center to center distance). Debris collects on and between the fins and filtered water passes through the fins and down the headers to the ECCS suction pipes. The strainer assembles are designed to prevent particles larger than 0.0625 inches from entering the RS and LHSI systems.

Suction openings for ORS and LHSI systems located in the containment sump are connected to their associated strainer assemblies by the new strainer header. The outside diameter (OD) of the new strainer header is machined cut to slip-fit into the existing suction openings ensuring that the gaps between the opening and the header piping do not exceed 0.0625 inches. For the IRS pump, the strainer header is connected to the pump well by installing a new well extension housing. The design of the strainer is such that the IRS, ORS and LHSI pumps no longer take suction directly from the containment sump, they now take suction from the containment annulus area via the strainers.

The RS strainer consists of two legs along the containment wall on either side of the containment sump. The bottom of the fins are approximately 6 inches off the containment floor which permits water to flow under the strainer and prevents "large" debris from building up around the fins thus blocking the effective surface area. The LHSI strainer modules are installed along the containment wall on the top of the RS strainer modules. See Figures 3j-1 and 3j-2 for the general layout of the new strainers.

In accordance with the IRS pump manufacturer and vendor technical manual, the pump well is required to be kept full of water, which lubricates the rotating parts within the pump and prevents damage caused by dry operation. Therefore, a 1½ inch pipe nipple with 0.0625-inch screened opening is installed on each IRS pump well extension housing near the bottom of the containment sump. This pipe nipple allows the water level in the containment sump and IRS pumps well to communicate.

The IRS pumps no longer take suction from the containment sump. They are directly connected to the strainer modules located outside the containment sump via a strainer header. The bleed line configurations within the containment sump area interfered with the new strainer design and were rerouted. In order to clear the interference, the existing four bleed lines entering into the pump casing have been removed and a single bleed line has been connected directly to the suction header entering the IRS pump casing via a flanged connection. The single bleed line provides proper mixing of the containment sump water as intended since the cold water now is injected into the suction header rather than the pump casing and allows cold water to mix prior to entering into the pump casing.

Each 4-inch bleed line has been reduced in size to 2 ½-inches near the sump. A flanged, 2-inch inline spring loaded type check valve is installed in each bleed line to close when its associated QS pump trips. Two new orifices have been sized to maintain the overall bleed line head loss identical to the existing bleed lines. The bleed line head loss and orifice sizing calculations have been updated to reflect these changes. The new piping configuration does not change the original design flow to the pump.

The check valves are inline spring loaded disc type with a properly sized spring designed to keep the check valve closed with minimal amount of leakage during operating conditions for 30 days post-LOCA. Valves, spectacle flanges, and associated hardware have been installed upstream and downstream of the check valves to facilitate ISI and IST requirements.

The scope of work necessary to provide sufficient clearance for the installation of the new containment sump strainer was comprised of, but not limited to modifying and/or relocating the following major items:

- Quench spray bleed lines.
- Dike wall interface with new strainer headers.
- Dike Wall Panel and Storage Rack Interferences.
- Containment sump level instrument debris shields.
- IRS pump test return lines and supports.
- Instrumentation and Instrumentation Rack interferences including tubing, conduit, drains and supports.

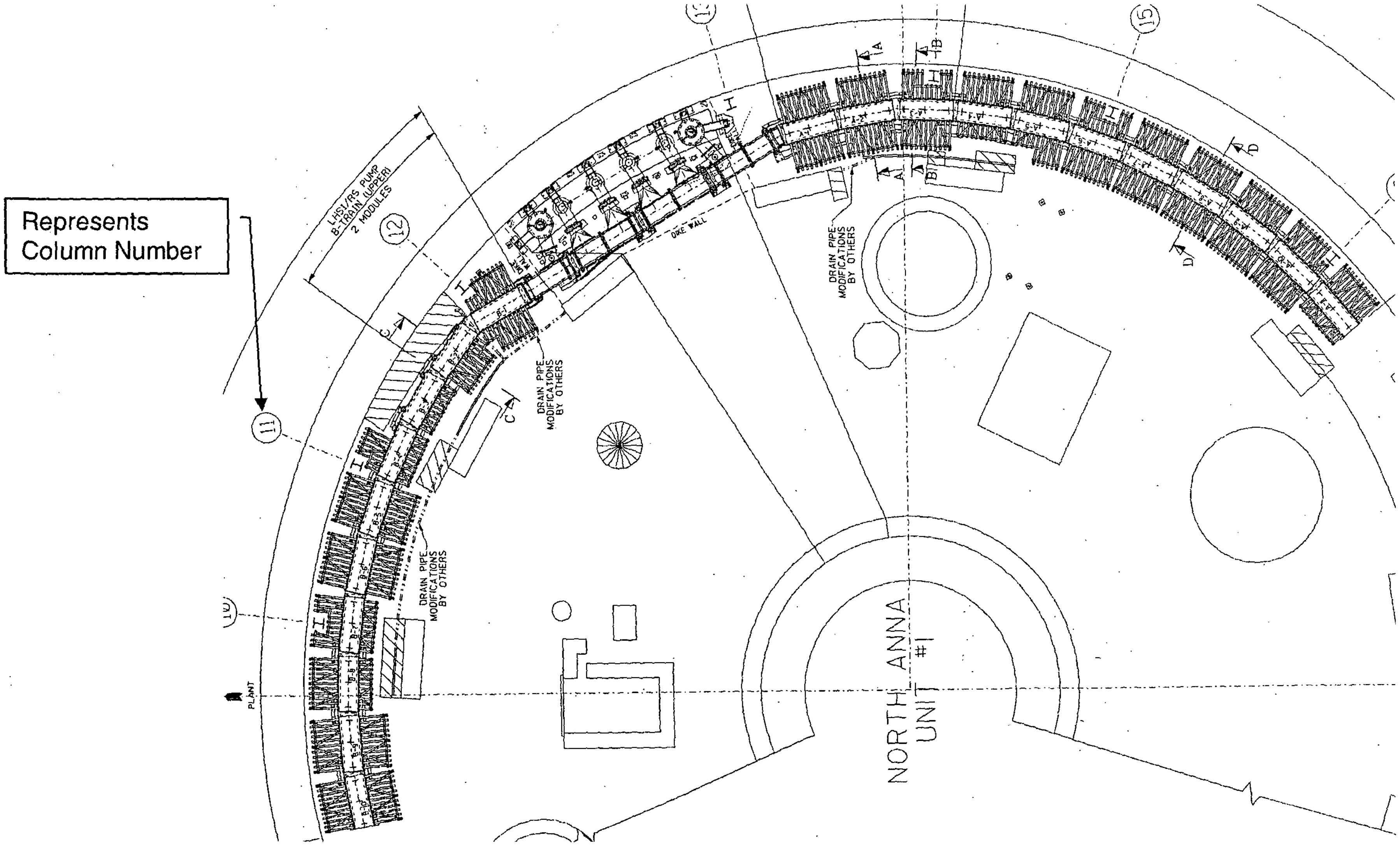


Figure 3j-1
NAPS Unit 1 Containment Sump Strainer Layout

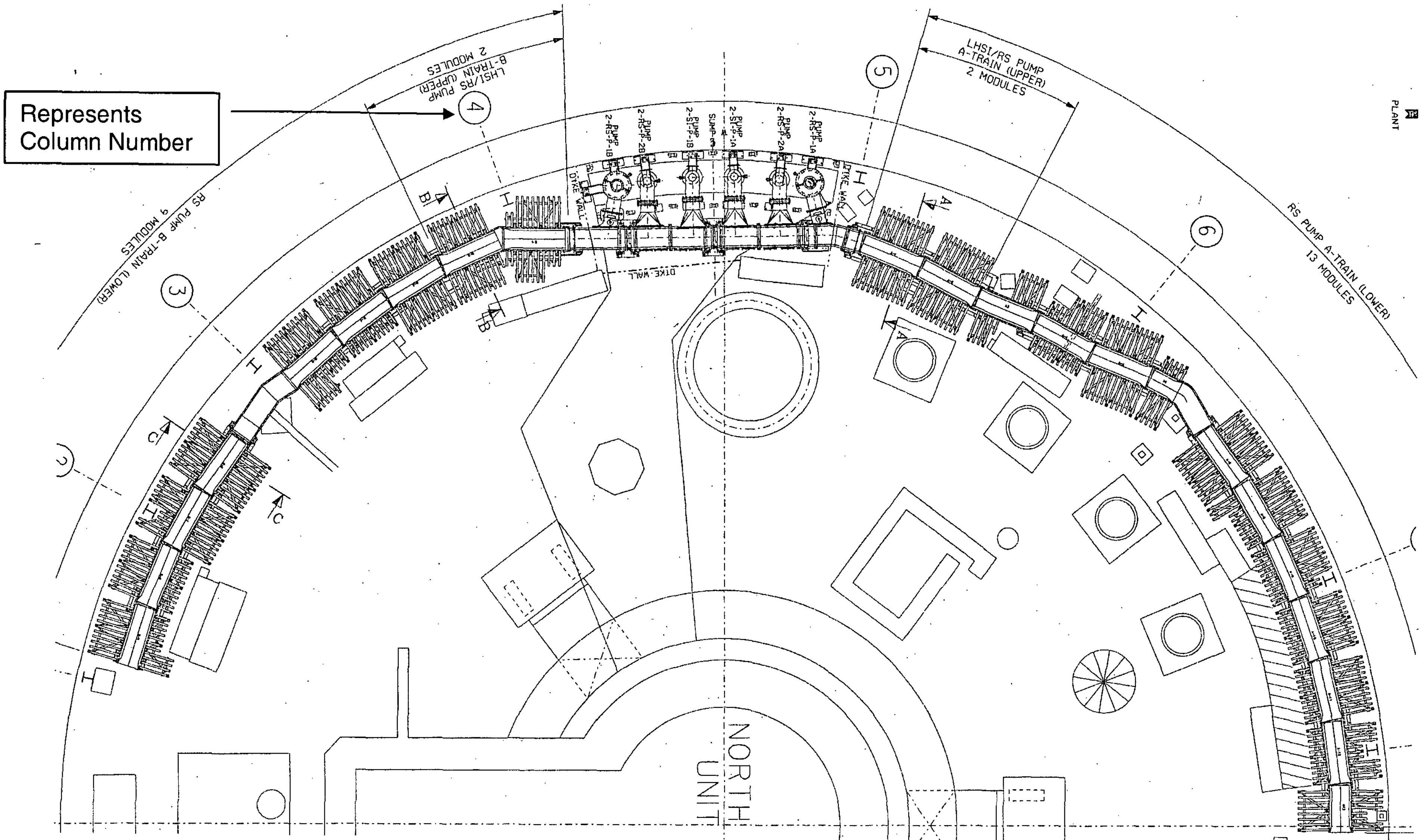


Figure 3j-2
NAPS Unit 2 Containment Sump Strainer Layout

3k - Sump Structural Analysis

Dynamic and static structural analyses of the replacement strainers was conducted using the Finite Element Analysis (FEA) method to qualify the strainer module consisting of train header modules and pump suction header modules.

Flanges between the pump elbow and transition piece were analyzed, buckling analysis of the pump housing was conducted, stress of the lugs attached to pump housing was analyzed, and the piping loads for the bleed lines on top of the transition pieces were analyzed for NAPS.

The strainer assembly is qualified for loadings associated with dead weight (including debris weight), seismic (including hydrodynamic mass), the differential pressure due to head loss, and thermal expansion.

FEA, using the ANSYS computer program, was performed in the structural qualification to verify the structural integrity of all components of the strainer assembly. For the perforated plates, equivalent solid plate analysis using the FEA model was used based on the guidance of American Society of Mechanical Engineers (ASME) Section III code, Appendix A-8000.

The following inputs were used in performing the structural analysis of the new strainer:

- A containment maximum temperature of 280°F during a LOCA was used.
- A value of 9.0 psid differential suction pressure loading corresponding to a fully debris-loaded strainer was used in the structural design.
- The structural damping is 2% for operating basis earthquake (OBE) and 3% for design basis earthquake or safe shutdown earthquake (SSE) seismic analyses.
- The design conditions for the strainer modules include dead weight, live load, suction pressure, thermal loading and seismic events.

The sump structural analysis also included the following design considerations:

- Stresses in Strainer Assembly
- Fatigue Analysis of Strainer Assembly
- Thermal Expansion
- Damping (OBE, & SSE Spectra) & Seismic Analysis
- Load Combinations and Acceptance Criteria
- Perforated Sheet Analysis
- Strainer Deflection
- Strainer Module Base Plates
- Support Bracket Connecting Bolts
- Weld Analysis
- Local Stress in Pump Housing
- Hydrodynamic Mass

The NRC staff conducted an audit of the NAPS actions to address GL 2004-02, and documented their findings in audit report (ADAMS ML072740400). The stresses in the containment sump replacement strainers, supports, anchorages, and welds were shown to meet the 1989 edition of the ASME Boiler and Pressure Vessel Code, section III, subsection NF requirements. From the buckling considerations, relevant components were shown to be stable. The calculations performed demonstrate that the strainer modules will meet their design function under the worst combination of postulated conditions. Based on these considerations, the NRC staff found that the design of the sump strainer assembly is structurally adequate, and that, from a structural perspective, it will perform its required safety function during a design basis accident.

3l - Upstream Effects

The purpose for the evaluation of upstream effects is to ensure that NAPS has appropriately accounted for potential hold up volumes, choke points, and other physical obstructions that could prevent water from draining to the sump. Any water held up by restrictions would not be available in the sump pool to provide coverage of the strainer and the required head above the strainer and would result in a reduction of NPSH margin.

The NRC staff conducted an audit of the NAPS corrective actions to address GL 2004-02 and documented their findings in audit report (ADAMS ML072740400). The staff focused its review of upstream effects on the drainage flowpaths through the refueling canal and reactor cavity because of the potential for the drains to these large volumes to act as choke points for retaining substantial quantities of water if the drains were to become blocked by debris. The NRC Staff noted that NAPS assumed that the refueling canal becomes filled with water, which is a conservative assumption, and that NAPS added a large drainage hole to the reactor cavity to ensure that a significant holdup volume would not occur in that location.

Based upon the information reviewed and summarized above, the staff concluded that water drainage in the NAPS containment would not be susceptible to being trapped in unanalyzed hold up locations.

The blowout panels in the reactor cavity could potentially block the drain from the refueling canal since it is only a 6-inch opening. To prevent blowout panels from blocking the opening, a raised steel dome with holes was installed over the refueling canal drain. The remainder of the refueling cavity has numerous drains through the reactor cavity penetrations and incore tunnel openings to drain the water even if some of the openings were blocked.

3m - Downstream Effects - Components and Systems

The downstream effects evaluation is currently being prepared in accordance with the new methodologies provided in WCAP-16406-P, Revision 1 and the NRC SER. The results of the revised evaluation will be provided once the evaluation has been finalized. In a letter dated December 13, 2007, the NRC granted NAPS an extension to complete the downstream effects evaluation.

Open items identified during the NRC audit for downstream effects are listed in Attachment 1 and will be addressed in the downstream effects evaluation.

3n - Downstream Effects – Fuels and Vessel

The NAPS Unit 2 audit report (ADAMS ML072740400) contains no evaluation of downstream effects for the fuel and vessel. The NAPS Unit 2 evaluation of downstream effects for the fuel and vessel was incomplete as described in Open Item 5.3-1, Downstream Effects-Core Blockage (see Attachment 1).

Since the audit, WCAP 16793, Rev. 0, has been published concerning the impact of fibrous, particulate, and chemical precipitant 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 NAPS 1 and 2. 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 precipitation on fuel clad surface, and
- Evaluation of chemical effects in the core region, including potential for plate-out on fuel cladding.

The WCAP states that the evaluation of these three areas identified above, in conjunction with other information, provides reasonable assurance of long-term core cooling for all plants. Specifically,

- 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 that a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue.

- 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 occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue.
- 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.
- 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.
- 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.

As discussed below, a plant specific evaluation has been performed that confirms the applicability of all of these conclusions to NAPS Units 1 and 2. Thus, the overall conclusion in the WCAP that reasonable assurance of acceptable long-term core cooling with debris and chemical products in the recirculating fluid is applicable to NAPS 1 and 2.

Applicability of WCAP-16793-NP to North Anna Units 1 and 2

Blockage at the Core Inlet

The AECL strainer design installed at NAPS 1 and 2 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 NAPS 1 and 2 has included bypass testing which determined the maximum amount of fiber bypass which would occur for the AECL 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 the vast majority (90%) of the fibers which bypassed the strainer were less than 1 mm long. The strainer hole size is 1/16 inch or 1.6 mm. Fiber bypass concentrations for the original debris composition show a near exponential decreasing trend with time. 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. The parameters of this analysis were selected to bound the United States Pressurized Water Reactor fleet by modeling the 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 three-loop 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. Converted upflow plants are less limiting since bypass flow in the Barrel/Baffle region can enter near the top of the core. The results are directly applicable to NAPS Unit 1 since NAPS Unit 1 is a Westinghouse three loop downflow plant and bounds NAPS Unit 2 which is a converted upflow plant. Thus, the WCOBRA/TRAC analysis presented in WCAP-16793-NP is directly applicable to NAPS 1 and bounds NAPS 2.

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.

<u>Collection of Debris on Fuel Grids</u>

As discussed above, the bypass testing of the AECL strainer design 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 United States Pressurized Water Reactor fleet. Thus, these calculations bound NAPS 1 and 2 and the conclusion that numerical and first principle analyses have demonstrated that core decay heat removal will continue applies to NAPS 1 and 2.

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, 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. This is representative of the fibrous debris expected at NAPS 1 and 2 and thus the conclusions of the WCAP are applicable to NAPS 1 and 2.

Chemical Deposition on the Fuel Cladding

The WCAP documents an Excel spreadsheet called LOCADM that will calculate the deposition of chemical precipitants and the resultant maximum clad temperature. Preparation of a NAPS calculation is in progress. When finalized, it is expected that the NAPS specific calculation will confirm the conclusion of the WCAP that acceptable long-term-core cooling in the presence of core deposits is applicable to NAPS 1 and 2. Completion of this calculation is expected by the end of March 2008.

Boric Acid Precipitation

As discussed above, the evaluation of the potential for blockage for NAPS 1 and 2 is entirely consistent with the evaluations documented in the WCAP. Since blockage will not occur for NAPS 1 and 2, the WCAP conclusion that the current accepted licensing calculations that demonstrate appropriate boric acid dilution to preclude boric acid precipitation remains valid is applicable to NAPS 1 and 2.

Summary

This evaluation demonstrates that all of the WCAP evaluations and conclusions are directly applicable to NAPS 1 and 2. This provides reasonable assurance that for NAPS 1 and 2 long-term core cooling will be established and maintained post-LOCA considering the presence of debris in the RCS and core.

3o – 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 NAPS 1 and 2 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.
- 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 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. Dominion 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 NAPS 1 and 2 containment sump pools 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 chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date, consistent with the schedule extension granted by the NRC in a letter dated December 13, 2007, when the evaluation has been finalized.

3p – Licensing Basis

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications. Several licensing basis changes associated with resolution of the sump issues considered in GSI-191 and GL 2004-02 have been implemented for NAPS Units 1 and 2 in the form of UFSAR revisions, an analysis methodology change and license amendment requests.

UFSAR

The NAPS UFSAR has been revised to reflect the installation of the new containment strainers for the RS and LHSI pumps, as well as the adoption and application of the GOTHIC code for containment analysis rather than the previous LOCTIC code. However, the current licensing basis for debris loading is being maintained until the downstream effects and chemical effects analyses have been completed, as well as any accompanying modifications, if required. Upon completion of these activities, the UFSAR will be revised to reflect the updated licensing basis.

Containment Analysis Methodology

The method for performing NAPS containment analyses for analyzing the response to postulated pipe ruptures inside containment was changed by converting from the Stone and Webster LOCTIC computer code to the Generation of Thermal-Hydraulic Information for Containments (GOTHIC) code. In a letter dated November 1, 2005 (Serial No. 05-745) (ADAMS ML053060266), Dominion submitted Topical Report DOM-NAF-3, "GOTHIC Methodology for Analyzing the Response to Postulated Pipe Ruptures Inside Containment," which documents the Dominion methodology for analyzing the containment response to postulated pipe ruptures using the GOTHIC code. The NRC approved Topical Report DOM-NAF-3 in a letter dated August 30, 2006 (ADAMS ML062420511). NAPS plant-specific applications of the DOM-NAF-3 methodology to effect GSI-191 changes associated with the RS pump start method and the containment air partial pressure operating limits, as noted below, were then implemented through the license amendment process.

License Amendment Request

A license amendment request was submitted by letter dated October 3, 2006 (Serial No. 06-849) (ADAMS ML062850195) for NRC review and approval in support of the installation of the new strainers and resolution of GSI-191 and NRC GL 2004-02. As detailed further below, the NRC has approved the license amendment request, and Dominion has implemented the approved license amendment for NAPS 1 and 2. Specifically, the license amendment request included the following changes:

- Revised the method for starting the IRS and ORS pumps in response to a DBA. Previously, the NAPS RS pumps were started by delay timers that were initiated when the containment pressure reached the Containment Depressurization Actuation (CDA) High High containment pressure setpoint. The license amendment request changed the start of the RS pumps to receipt of a CDA High High pressure signal coincident with a refueling water storage tank (RWST) Level-Low signal. This change ensures that adequate water volume is available to submerge the new containment sump strainer, prior to the pumps taking suction from the strainer, and meets the safety analysis acceptance criteria. The revised TS surveillance requirements verify that each RS pump automatically starts on a CDA High High test signal coincident with the receipt of an RWST Level Low test signal. A plant modification associated with the license amendment request was required to install the new RS pump start circuitry.
- Replaced the current LOCTIC containment analysis methodology for analyzing the response to postulated pipe ruptures inside containment, including loss of coolant accident (LOCA) and main steam line break (MSLB) events, with the NRC-approved GOTHIC evaluation methodology discussed in Dominion Topical Report DOM-NAF-3-0.0-P-A. The change to the GOTHIC code from the LOCTIC code provides margin in LOCA peak containment pressure and other accident analysis results for both the existing and the revised GSI-191 licensing bases.
- Lowered the maximum containment operating temperature limit, modified the containment air partial pressure operating limit, and lowered the plant setpoint and TS allowable values for the RWST Level Low-Low function that initiates safety injection recirculation mode transfer.
- Revised the TS surveillance requirements for containment sump inspection to be consistent with the planned design for separate strainers for the LHSI and RS systems.
- Revised the TS value for Pa, the peak calculated containment pressure from a LOCA, based on the GOTHIC containment analyses.
- Revised the LOCA Alternate Source Term (AST) analysis to include the effects from changing the RS pump start methodology and from the other modification associated with the GSI-191 project.

The NRC approved the license amendment request for NAPS Units 1 and 2 in Amendments 250/230, respectively, in a letter dated March 13, 2007 (ADAMS ML070720043). Implementation of these changes was completed during the spring 2007 refueling outage for NAPS Unit 2 and during the fall 2007 refueling outage for NAPS Unit 1.

ATTACHMENT 1

RESOLUTION OF NRC AUDIT OPEN ITEMS

VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)
NORTH ANNA POWER STATION

NRC GL 2004-02 AUDIT OPEN ITEMS
NORTH ANNA UNITS 1 AND 2

Open Item No. and Subject	Item	Resolution
Open Item 3.6-1 Temperature Scaling of Head Loss Test Data	The licensee scaled test head losses to plant sump conditions based only on temperature-driven viscosity variations. Test phenomena driven by differential pressure (e.g., opening of paths through the bed) should be considered as well. The licensee should evaluate this issue and provide a summary of the method and results to the staff in its supplemental response to GL 2004-02 due by the end of December 2007.	Refer to Section 3f for the response to this open item.
Open Item 3.6-2 Justification for Time-Dependent Head Loss Assumptions	The licensee assumed that at the beginning of low head safety injection operation in the recirculation mode there would be no debris accumulation on the low head safety injection strainer, and that the strainer head loss due to debris would reach the peak thin bed head loss after a period of time. The licensee should provide the basis for these assumptions in its supplemental response to GL 2004-02.	Refer to Section 3f for the response to this open item.
Open Item 3.7-1 Net Positive Suction Head Available Calculation	The calculated net positive suction head available margins for the low head safety injection, inside recirculation spray and outside recirculation spray pumps were non-conservative. The margins for these pumps were overestimated by approximately 0.6 feet of	Refer to Section 3g for the response to this open item.

	head because of an error in the calculation of the static head of liquid. The licensee should evaluate this issue and provide a summary of the method and results to the staff in its supplemental response to GL 2004-02.	
Open Item 5.3-1 Downstream Effects-Core Blockage	Although downstream evaluations were in progress during the audit, the licensee has not made any final conclusions as to whether the cores at North Anna Power Station could be blocked by debris following a LOCA, and this area is incomplete. The licensee should summarize the method and results of its evaluation of this issue in its GL 2004-02 supplemental response.	See Section 3n "Downstream Effects – Fuel and Vessel" for Dominion's response to this open item.
Open Item 5.3-2 Downstream Effects Evaluations Preliminary	The licensee's evaluations of the downstream effects of debris on systems and components are preliminary, based in part on the generic methodology of WCAP-16406-P which is under review by the NRC staff. NAPS will reassess the evaluation based on the conclusions and findings associated with the staff's review of WCAP-16406-P Revision 1. The licensee should provide the staff a summary of the method and results of this evaluation.	The Downstream Effects – Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date. Open Item 5.3-2 will be addressed when the Downstream Effects - Components and Systems evaluation has been completed.
Open Item 5.3-3 ECCS Instrument Locations	The evaluation documented that the ECCS instrument locations are adequate because of an assumption of "good engineering practice." This assumption needs to be verified, such as by means of isometrical drawings or an ECCS survey. The licensee should provide the staff a summary of the method and results of this verification.	This item is being evaluated as part of the Downstream Effects - Components and Systems evaluation, which is still ongoing, and its results will be provided at a later date. Open Item 5.3-3 will be addressed when the Downstream Effects - Components and Systems evaluation has been completed.

Open Item 5.3-4 Debris Bypass Testing	The licensee had not made a final determination on how the bypass testing data is going to be implemented in the downstream effects evaluation for ECCS and internal vessel components. The licensee should provide the staff a summary of the method and results of its bypass testing.	See Section 3n for a detailed discussion on bypass flow testing with respect to the vessel and core. The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-4 will be addressed.
Open Item 5.3-5 Fixed Throttle Valve Setting	The downstream component evaluation did not reference operating procedures or testing history in order to demonstrate high confidence that throttle valves will remain in their fixed position during ECCS operation. Throttle valve fixed position is the basis for assuming the system's hydraulic resistance to be fixed. The licensee should address the full potential range of throttle valve positions in their revised downstream evaluation	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-5 will be addressed.
Open Item 5.3-6 Quantification and Assessment of Downstream Effects That Cause Seal Leakage	The licensee did not quantify seal leakage associated with downstream effects into the Auxiliary Building, nor evaluate the effects on equipment qualification, sumps and drains operation, or on room habitability. The licensee should summarize the method and results of its evaluation of these subjects in its GL 2004-02 supplemental response.	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-6 will be addressed.
Open Item 5.3-7 Range of System Flows	The licensee did not fully define the range of fluid velocities within piping systems. Fluid velocities used were based on nominal system operating characteristics and did not take into account the range of possible system flows. NAPS staff	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-7 will be addressed.

	should re-assess ECCS flow balances based on the results of system and component wear evaluations and should provide a summary of the method and results to the NRC staff.	
Open Item 5.3-8 ECCS Minimum and Maximum Operating Points	The preliminary downstream component evaluation did not consider the use of minimum and maximum system operating points; instead, best-efficiency performance values were used. The ECCS operating point values were not referenced back to system bases calculations. The licensee should evaluate this issue and provide a summary to the staff.	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-8 will be addressed.
Open Item 5.3-9 Use of Manufacturer's Pump Performance Curves	The pump performance inputs considered in the preliminary downstream components evaluation were obtained from manufacturer's pump performance curves. The evaluation should consider the use of degraded pump curves or in-service testing curves as these curves better represent actual system operating conditions. The licensee should evaluate this issue and provide a summary to the staff.	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-9 will be addressed.
Open Item 5.3-10 Overall Downstream ECCS Evaluation	The licensee had yet to perform an overall system evaluation that integrates the results of the downstream components evaluation. The evaluation should address compliance with 10 CFR 50.46, "Long Term Core Cooling." The licensee should evaluate this issue and provide a summary to the staff.	The Downstream Effects - Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date, at which time Open Item 5.3-10 will be addressed.

Open Item 5.4-1 Evaluate Chemical Effects	The licensee's chemical effects analysis was incomplete at the time of the audit. Also, the licensee has not evaluated the contribution of coatings to chemical effects by: (1) leaching constituents that could form precipitates or affect other debris; and (2) changing form due to the pool environment. Since the licensee's integrated chemical effects testing plans have not been completed, the staff could not review the application of the debris bed head loss acceptance criteria to verify that the long-term and short-term acceptance criteria are bounding with respect to intermediate conditions. The licensee should provide the staff a summary of the method and results of its chemical effects evaluation and testing.	The chemical effects evaluation is ongoing. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation. The results of this testing will be provided at a later date, at which time Open Item 5.4-1 will be addressed.

ATTACHMENT 2

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION DATED FEBRUARY 9, 2006

**VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)
NORTH ANNA POWER STATION**

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION DATED FEBRUARY 9, 2006

NORTH ANNA POWER STATION UNITS 1 AND 2

NRC RAI # 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.

Dominion Response

The response to the above question is detailed in the NAPS audit report (ADAMS ML072740400) Section 3.2 (Debris Generation/Zone of Influence) and Table 3 (Bounding LOCA-Generation Insulation Debris Quantities).

NRC RAI # 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

(c) 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).

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 3

Identify the amount (surface area) and material (e.g., aluminum) for any scaffolding stored in containment. Indicate the amount, if any, that would be submerged in the containment pool following a LOCA. Clarify if scaffolding material was included in the response to Question 2.

Dominion Response

Storage of scaffolding materials is provided on the 241' and 262'-10" elevations of containment. The maximum flood elevation in containment is calculated to be 225'-7". Therefore, no accident scenarios exist for which the scaffold would be submerged in the debris pool post LOCA. The scaffolding in each containment building includes 22,816 ft^2 of zinc and 3180 lb_m of zinc.

NRC RAI # 4

Provide the type and amount of any metallic paints or non-stainless steel insulation jacketing (not included in the response to NRC RAI # 2) that would be either submerged or subjected to containment spray.

Dominion Response

The NAPS audit report (ADAMS ML072740400) contains a detailed description and evaluation of coatings for NAPS.

The original construction insulation specification stated to use stainless steel jacketing insulation system. The current specification for the installation of insulation at NAPS states that: "The surface covering for insulation inside containment shall be Type 304 stainless steel. (S.S.)" and that: "The quantity of unjacketed insulation inside containment is to be kept to a minimum." However, to maintain dose As Low as Reasonably Achievable (ALARA), the specification allows jacketing (on a case by case basis) with a fiberglass cloth or silicone impregnated fiberglass fabric with stainless steel mesh for difficult or time consuming jacketing jobs in high radiation areas. Use of this jacketing in lieu of S.S. requires an Engineering evaluation for High Energy Line Breaks (HELB) and debris generation.

If the insulation jacketing and metallic coating is required to be addressed by chemical effects, this will be addressed when the evaluation has been finalized. The chemical effects evaluation is currently ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

This information was requested with respect to chemical effects. Dominion's chemical effects evaluation is ongoing, and the results of this evaluation will include this information. The chemical effects evaluation will be provided to the NRC at a later date when the evaluation has been finalized. The NRC granted an extension to complete the chemical effects evaluation in a letter dated December 13, 2007.

NRC RAI # 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

Dominion has removed Microtherm insulation from inside NAPS Unit 2 containment. There was no Microtherm insulation inside the Unit 1 containment. Calcium silicate insulation in the steam generator and pressurizer rooms was replaced with Paroc and Tempmat insulation.

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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, deionized 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 13

Results from the ICET #1 environment and the ICET #5 environment showed chemical products appeared to form as the test solution cooled from the constant 140°F test temperature. Discuss how these results are being considered in your evaluation of chemical effects and downstream effects.

Dominion Response

The chemical effects evaluation is ongoing, and the results of the revised evaluation will be provided at a later date when the evaluation has been finalized. An extension has been granted in a letter dated December 13, 2007 in reference to the chemical effects evaluation.

NRC RAI # 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 demonstrated 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.

Dominion Response

See Section 3h "Coatings" of GL 2004-02 NAPS Unit 1 and 2 Supplemental Response.

NRC RAI # 29

Your GL response indicates that you may pursue a reduction in the radius of the zone of influence (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 justification regarding how these deviations are accounted for with the test demonstrating the proposed ZOI.

Dominion Response

See Section 3h "Coatings" of GL 2004-02 NAPS Unit 1 and 2 Supplemental Response.

NRC RAI # 30

The NRC staff's safety evaluation (SE) 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. 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.

Dominion Response

NAPS is classified as a high fiber plant, and therefore postulates that a high head loss thin bed could form in accordance with the NRC SE guidance. Plant specific head loss testing treated all coating as particulate. Refer to Section 3f of the supplemental response for additional details.

NRC RAI # 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

Dominion Response

The Downstream Effects – Components and Systems evaluation is still ongoing, and the results of this evaluation will be provided at a later date. Open Item 5.3-2 will be addressed when the Downstream Effects - Components and Systems evaluation has been completed. An extension has been granted in a letter dated December 13, 2007 in reference to the Downstream Effects – Components and Systems evaluation.

NRC RAI # 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?

Dominion Response

Dominion considered an active strainer design, but abandoned the concept for the inherent reliability of a robust passive design. No further active approaches are being considered at this time.

NRC RAI # 33

You stated that for materials for which no ZOI values were provided in the Nuclear Energy Institute (NEI) guidance report or the 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.

Dominion Response

Refer to Section 3b of the supplemental response for information on ZOI values applied for debris generation.

NRC RAI # 34

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.

Dominion Response

The response to the above question is detailed in the NAPS audit report (ADAMS ML072740400) Section 3.3 (Debris Characteristics).

NRC RAI # 35

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.

Dominion Response

Refer to Section 3e of the supplemental response for the resolution of this RAI.

NRC RAI # 36

Are there any vents or other penetrations through the strainer control surfaces which 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.

Dominion Response

The quench spray bleed lines that inject into the IRS pump suction lines penetrate the control surface of the RS strainer and connect the volume internal to the strainer with the containment atmosphere above the minimum water level through the bleed lines connected to the spray nozzle headers. Communication between the containment sump strainer and the containment atmosphere through the spray header nozzles is prevented by in-line spring-loaded check valves in the bleed lines. Otherwise, the RS strainer is fully submerged during operation.

NRC RAI # 37

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 the drains might occur, do water hold-up calculations used in the computation of NPSH margin account for the lost or held-up water resulting from debris blockage?

Dominion Response

The NRC audit report for North Anna accurately identifies that the NPSH available calculation assumes that the refueling canal drain line does not pass any water in determining the minimum water level. This was a conservative approach for calculating NPSHa. However, there is a raised steel dome with holes over the refueling canal drain as noted in the North Anna UFSAR, Revision 43, Section 6.2.1.3.2.5. Given the location of the refueling canal and that insulation in the spray region above the canal is jacketed and not subject to spray generation, it is unlikely that the refueling canal drain line would be blocked fully.

Refer to Section 3l of the supplemental response for additional information.

NRC RAI # 38

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?

Dominion Response

Refer to Section 3f of the supplemental response for the evaluation of this RAI.

NRC RAI # 39

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.

Dominion Response

NAPS did not credit a computational fluid dynamics (CFD) analysis to calculate the flow of water in the containment pool during the recirculation phase of a LOCA as an input to the determination of debris transport fraction. The NRC staff conducted an audit of the NAPS corrective actions to address GL 2004-02, and documented their findings in audit report (ADAMS ML072740400). Their report contains a detailed description of debris transport for NAPS.

NRC RAI # 40

In GL 2004-02, item 2.d.iv, the NRC requested licensees to provide the basis for concluding that the water inventory required to ensure adequate ECCS or Containment Spray System (CSS) recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths. NAPS responded that Dominion is planning to perform additional verification walkdowns during upcoming refueling outages. Is North Anna planning to write a supplemental response to this GL with the results of these walkdowns? If so, when will the NRC get the response?

Dominion Response

Subsequent to the North Anna response to GL 2004-02 dated September 1, 2005, additional walkdown verifications were not performed for upstream effects after it was concluded that the original GSI-191 walkdowns provided sufficient detail to support the calculations of water holdup. Programs, such as the design change process, are in place to evaluate plant changes that may create new chokepoints or holdup areas that could affect the assumed holdup volumes.

The Staff concluded that water drainage in the NAPS containment would not be susceptible to being trapped in unanalyzed holdup locations. Refer to Section 3l of the supplemental response for additional detail.