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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Watts Bar Nuclear Plant, Unit 2
NRC Docket No. 50-391

Subject: **Watts Bar Nuclear Plant (WBN) Unit 2 - Response to Generic Letter (GL) 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors**

TVA to NRC letter dated September 10, 2010 (Reference 2) provided Unit 2's response to GL 2004-02. This letter supersedes that response (and the commitments therein) and provides information to support NRC verification that the corrective actions to address GL 2004-02 are adequate for Unit 2. This response was prepared using the guidelines set forth in Reference 1.

Enclosure 1 provides the necessary supplemental responses addressing GL 2004-02 actions for Unit 2 using the guidelines set forth in Reference 1 and the Unit 1 responses in Reference 3. Enclosure 2 addresses the 11 remaining open items that are applicable to Unit 2 from the NRC's audit of the WBN GL 2004-02 resolution described in Reference 4. Enclosure 3 contains the Requests for Additional Information (RAIs) from Unit 1's Request for Additional Information Supplemental Response to GL 2004-02 (References 5 and 6) with Unit 2 responses.

Enclosure 4 provides the list of commitments made in this letter. If you have any questions, please contact William Crouch at (423) 365-2004.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 4th day of March, 2011.

Respectfully,

[signature]

David Stinson
Watts Bar Unit 2 Vice President

A116
NRR

References:

1. NRC letter to Nuclear Energy Institute (NEI) dated November 21, 2007, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses" (ADAMS Accession No. ML073110269)

2. TVA Letter to NRC dated September 10, 2010, "Watts Bar Unit 2 Response to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" (ADAMS Accession No. ML102580175)

3. TVA Letter to NRC dated March 31, 2008, "Watts Bar Nuclear Plant (WBN) Unit 1 - Supplemental Response to Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (PWR) - Notice of Completion (TAC No. MC4730)" (ADAMS Accession No. ML081090500)

4. TVA letter to NRC dated July 3, 2006, "Watts Bar Nuclear Plant (WBN) Unit 1 - Generic Letter 2004-02 - Request for Additional Information Regarding the Nuclear Regulatory Commission Staff Audit on the Containment Sump Modifications (TAC No. MC4730)" (ADAMS Accession No. ML062120472)

5. TVA Letter to NRC dated March 3, 2009, "Watts Bar Nuclear Plant (WBN) Unit 1 - Response to Request for Additional Information Regarding Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC. No. 4730)" (ADAMS Accession No. ML090720868)

6. TVA Letter to NRC dated June 3, 2010, "Draft Responses to Requests for Additional Information Related to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage During Design Basis Accidents at Pressurized-Water Reactors" (ADAMS Accession No. ML101590373)

7. NRC letter dated February 7, 2007, "Watts Bar Nuclear Plant, Unit 1 – Audit Report of New Strainer Design in Response to GL 2004-02 and Generic Safety Issue -191" (ADAMS Accession No. ML070380083)

8. NRC Report dated November 22, 2006, "Plant Audit Report-Watts Bar Unit 1 Nuclear Plant New Sump Design in Response to Audit Report" (ADAMS Accession No. ML062120469)

9. NRC document dated March 2008, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing" (ADAMS Accession No. ML080230038)

Enclosures:

1. Supplemental Response to Address GL 2004-02 Actions at Unit 2 Using Revised Content Guide for GL 2004-02 Supplemental Responses
2. Unit 1 NRC Audit Open Items With Unit 2 Responses
3. RAIs From Unit 1's RAI Supplemental Response to GL 2004-02 With Unit 2 Responses
4. List of Regulatory Commitments

Attachment to Enclosure 2:

1. Calculation MDQ00200020110377, Rev. 0, "Watts Bar Unit 2 Reactor Building GSI-191 Debris Generation Calculation"

Attachments to Enclosure 3:

1. Test Tank Protocol
2. General Debris Preparation Criteria
3. Additional Test Tanking Inputs

cc (Enclosures):

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Enclosure 1

Supplemental Response to Address GL 2004-02 Actions at Unit 2 Using Revised Content Guide for GL 2004-02 Supplemental Responses

This Enclosure provides information to support NRC verification that the corrective actions to address GL 2004-02 are adequate for Unit 2. It was developed using the guidelines contained in Reference 1.

1. Overall Compliance:

Provide information requested in GL 2004-02 Requested Information Item 2(a) regarding compliance with regulations.

GL 2004-02 Requested Information Item 2(a)

Confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis described above.

TVA Response

The emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02 for debris loading conditions at the time of fuel load for Unit 2. Unit 2 will install sump modifications per the requirements of the Generic Letter that are very similar to the modifications made to Unit 1. The physical differences are specifically enumerated in the response to ***Item*** **2**.

The NRC performed an audit of the Unit 1 sump evaluations and issued a final report by letter dated February 7, 2007 (Reference 7). This letter concluded that "overall the staff's impression is that the WBN new sump modifications appear to be robust with sufficient design margin."

Unit 2's containment is a mirror image of design to Unit 1's containment. Therefore, walkdowns, debris generation calculations, debris transport, and downstream effects will be the same for Unit 2 as for Unit 1 with the exception of items noted in the following. The containment walkdowns, debris generation calculations, debris transport calculations, downstream effects evaluations for blockage and long-term wear, and allocation of an allowance for chemical effects have been completed for Unit 1 and therefore for Unit 2 as follows.

Containment Walkdowns

Containment walkdowns were performed at Unit 1 to support the analysis of debris blockage as identified in the GL. The walkdowns were performed by personnel from Enercon, Westinghouse Electric Corporation (WEC), ITSC, and Transco in consultation with TVA personnel using the guidelines provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1. As noted previously, these walkdowns apply to Unit 2 due to Unit 2 being a mirror image of Unit 1. A similar confirmatory walkdown for loose debris will be performed on Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup.

Supplemental Response to Address GL 2004-02 Actions at Unit 2 Using Revised Content Guide for GL 2004-02 Supplemental Responses

Debris Generation Analysis

An analysis to establish the types, quantities, and locations of debris generated during a loss of coolant accident (LOCA) event in which the plant enters the recirculation mode was performed using NEI Guidance Report 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," as supplemented by the NRC in the "Safety Evaluation by The Office of Nuclear Reactor Regulation Related to NRC GL 2004-02," Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology." The predicted debris generation for Unit 2 is the same as for Unit 1 with the exception that Unit 2's containment does not contain Min-k (microtherm) insulation and it does not contain 3M fire-wrap.

Debris Transport Analysis

This analysis was based on the NEI 04-07 guidance report for refined analyses as supplemented by the NRC's safety evaluation report (SER), as well as the refined methodologies suggested by Appendices III, IV, and VI of the SER. The specific effect of each mode of transport was analyzed for each type of debris generated, and a logic tree was developed to determine the total transport to the sump screens. The general arrangement inside the Unit 1 and Unit 2 containments are mirror images, and the pump capacities and flow rates are the same. Thus, the Unit 1 transport analysis applies to Unit 2.

Downstream Effects Evaluation

The evaluation of downstream effects was performed in accordance with the methodologies in Topical Report No. WCAP-16406-P, Revision 01, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191." This analysis applies to Unit 2 with the following exception: the Unit 1 design uses a combination of orifices and throttle valves to control the flow split in the chemical and volume control system (CVCS) and safety injection (SI) system lines to the RCS loops post-accident, whereas Unit 2 will use specially designed throttle valves.

Chemical Effects Evaluation

A comparison of the NRC industry integrated chemical effects test program Test 5 and the WBN plant-specific parameters was performed. The comparison concluded that the critical parameters in the integrated chemical effects test program Test 5 are similar to the WBN plant parameters. To account for chemical effects, margin was added to the WBN strainer area design requirements.

Based on the results of the debris generation and transport analyses, the original Unit 2 containment sump intake screens will be replaced with an advanced design containment sump strainer arrangement under Engineering Document Construction Release (EDCR) 53580. A "stacked disk" strainer design was selected to maximize the available sump flow area in the existing containment sump structure "footprint." The advance design strainer increased the available containment sump strainer area from approximately 200 ft^2 to approximately 4,600 ft^2. Additional strainer head loss tests were conducted in July 2010 on the Unit 1 strainer configuration. The Unit 2 strainer geometry closely resembles the Unit 1 strainer element configuration. The physical differences are specifically enumerated in the response to ***Item 2***. These tests further evaluated the performance of the advanced strainer design; see response to ***Item 3.f.4***.

2. ***General Description of and Schedule for Corrective Actions:***

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests, or explain how regulatory requirements will be met as per Requested Information *Item 2(b).*

GL 2004-02 Requested Information Item 2(b)

A general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this GL. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

TVA Response

Modifications to Unit 2 to comply with the GL will be completed prior to fuel load. The modifications are similar to those made for Unit 1. The specific modifications and unit differences are:

a. The sump intake structure will be modified to an advanced strainer design (EDCR 53580). The design is the same as that used for Unit 1 except that the strainer stack to plenum opening was increased in size. This change reduces the strainer pressure drop, thus providing more margin to plugging the strainer when compared to Unit 1.

b. Min-K (microtherm) insulation and 3M fire-wrap are not used in the Unit 2 containment. This reduces the post-LOCA fiber debris source term for Unit 2 compared to Unit 1. The only fiber source term for sump debris transport is the latent dust and dirt.

c. New throttle valves have been procured for installation in the CVCS and SI lines to the RCS. The valves will be installed under EDCR 54783. Unit 1 uses a combination of orifices and valves to achieve the required pressure drop for injection line balancing. Unit 2 will not include the orifices. The new valves will be opened sufficiently to preclude downstream blockage and reduce the number of components that need to be considered for potential debris erosion.

d. The original Model D-3 steam generators (SGs) are installed in Unit 2 while Unit 1 has installed new SGs. Unit 1 had the Model D-3 SGs installed at the time of their containment walkdowns.

These differences, with the exception of **d.**, both individually and in aggregate, add margin to the Unit 2 design when compared to the Unit 1 design. Difference **d.** is neutral. Given that the outward configuration of the Unit 2 strainers is the same as that of the Unit 1 strainers, the testing performed on the Unit 1 strainers is applicable to and bounding for the Unit 2 strainers with regard to maximum pressure drop.

3. Specific Information Regarding Methodology for Demonstrating Compliance:

3.a. ***Break Selection***

The objective of the break selection process is to identify the break size and location that present the greatest challenge to post-accident sump performance.

3.a.1. *Describe and provide the basis for the break selection criteria used in the evaluation.*

TVA Response

The following break locations were selected and analyzed for WBN:

- Break 1: Locations in the RCS with the largest potential for debris generation.
- Break 2: Locations with two or more different types of debris.
- Break 3: Locations with the most direct path to the sump.
- Break 4: Locations with the largest potential particulate to insulation ratio.
- Break 5: Locations that would generate debris that could potentially form a thin-bed.

The objective of the break selection process was to determine the break size and possible locations that result in the greatest debris generation and/or the debris generation and transport combination that present the greatest challenge to post-accident sump performance. Additionally, breaks that result in a "thin-bed" effect were given consideration since these also have the potential to significantly impair sump screen performance.

3.a.2. *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*

TVA Response

Break locations were selected based on the accident scenarios that could lead to ECCS recirculation, the size of the pipe break, and the proximity of other insulated pipes or equipment. Secondary line breaks were considered in the evaluation but eliminated as bounding events. Secondary line breaks have a smaller zone of influence (ZOI) for destruction (due to lower pressure), are terminated by operator action (feedwater and auxiliary feedwater isolation), and do not require sump recirculation for reactor coolant system decay heat removal. Only minimal intermittent operation of the containment spray system in the containment sump recirculation mode for long term containment temperature reduction may be required if other means are not available.

3.a.2. *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

TVA Response

The five different break scenarios discussed in the response to ***Item 3.a.1.*** were evaluated for the accident scenario that requires operation in the containment sump recirculation mode (i.e., large break loss-of-coolant) as follows.

Break 1 – Largest Potential for Debris Generation

The largest quantity of insulation in containment is located in the RCS loops near each of the SGs and reactor coolant pumps (RCPs). Due to the size of the primary RCS loop piping and the quantity of insulation in close proximity to these pipes, a double-ended guillotine break of one of the primary loop pipes presents the limiting case. The inside diameters of the primary RCS pipes are 27.5" for the cold legs, 29" for the hot legs, and 31" for the crossover legs. A break in one of the 31" inner diameter crossover legs would create the largest ZOI. However, depending on the exact location of various types of insulation, a break in the smaller hot or cold leg could result in the generation of a larger quantity of debris. Therefore the worst case location was considered for each of the four loops.

Break 2 – Two or More Types of Debris

The principal types of transportable debris for Unit 2 are latent fiber and paint chips. All breaks considered encompass this scenario since multiple types of debris exist in each of the loop areas.

Break 3 – Most Direct Path to the Sump

The ECCS recirculation sump is located beneath the refueling cavity in the lower containment. This area is between loops 3 and 4. Therefore, breaks in these loops would have a direct path to the sump.

Break 4 – Largest Particulate to Insulation Ratio

Of the three principal debris types in lower containment, Reflective Metal Insulation (RMI) is the least problematic. RMI does not transport as easily as the particulates and is not a major contributor to head loss. The bounding case is the one that generates the most destruction of coatings. The debris generation analysis identified that a break in the crossover leg near the SG nozzle generated the most particulate debris.

Break 5 – Potential Formation of the Thin-Bed Effect

This scenario addresses the generation of a small quantity of fibrous debris that, after its transport to the sump screen, could form a uniform thin bed that would subsequently filter sufficient particulate debris to create a relatively high head loss. Unit 2 does not have large amounts of fibrous material inside containment. The only fibrous material present in the Unit 2 containment that can be transported to the sump are those in the dirt and debris. Some mineral wool insulation is used inside containment, but it is not used in locations within the ZOI for any LOCA. A small quantity of mineral wool (1.57 ft^3) is used where the under vessel in-core instrument tubes penetrate the crane wall. Mineral wool is also used inside the guard pipes on the main feedwater lines outside of the crane wall where the lines penetrate the steel primary containment.

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

The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; and (2) the amount of debris generated by the break jet forces.

3.b.1. *Describe the methodology used to determine the ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report/SE, or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.*

TVA Response

As documented in NEI-04-07, the destruction pressures for various insulation materials were determined by performing air jet or water/steam jet tests. These tests were carried out by directing high-energy jets on various insulation targets at varying distances. The destruction pressures were then quantified by observing the effects of the jet on the insulation and the corresponding stagnation pressure in the flow field.

In a pressurized water reactor (PWR) containment building, the worst case hypothetical pipe break would be a double-ended guillotine break (DEGB). In a DEGB, jets of water and steam would blow in opposite directions from the severed pipe. One or both jets could impact an obstacle and be reflected in different directions. To take into account the double jets and potential jet reflections, NEI-04-07 recommended using a spherical ZOI centered at the break location to determine the quantity of debris that could be generated by a given line break. Since different insulation types have different destruction pressures, different ZOIs must be determined for each type of insulation.

The ZOIs for WBN were established using the NEI-04-07 methodology. Items not specifically addressed in the methodology were addressed consistent with the NRC SER issued for NEI-04-07.

3.b.2. *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*

TVA Response

Consistent with NEI-04-07 and the associated NRC SER, the equivalent spherical ZOI radii divided by the break diameter (r/D) for each representative material in the WBN containment was established as follows:

ZOI Radii for WBN Debris Types

Insulation Type	ZOI Radius/Break Diameter (r/D)
Protective Coatings (epoxy and epoxy-phenolic paints)	10.0*
Reflective Metal Insulation	28.6

* NRC SER recommends a ZOI of 10.0 r/D as a conservative estimate.

3.b.3. *Identify if destruction testing was conducted to determine ZOIs. If such testing has not been previously submitted to the NRC for review or information, describe the test procedure and results with reference to the test report(s).*

TVA Response

No destructive tests were conducted for Unit 2.

3.b.4. *Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations.*

TVA Response

Debris generation calculations were performed for a break in the 31" inner diameter crossover leg at the base of the SG for each of the primary system loops. The quantity of each debris type generated for each break location is as follows:

Debris Source Term for a Loop 1 Crossover Leg Break

Debris Type	Small Pieces	Large Pieces	Total
Stainless Steel RMI	75,902 ft^2 (75%)	25,300 ft^2 (25%)	101,202 ft^2

Debris Type	Fines	Large Pieces	Total
Latent Fiber	6.25 ft^3	0 ft^3	6.25 ft^3

Debris Type	Fines	Chips	Total
Dirt/Dust	85 pound	0 pound	85 pound
Phenolic Paint	137 pound	0 pound	137 pound
IOZ Paint	1,152 pound	0 pound	1,152 pound
Alkyd Paint	44 pound	0 pound	44 pound
Epoxy Paint	25 pound	0 pound	25 pound
Carboline 295	752 pound	0 pound	752 pound
Silicone Paint	42 pound	0 pound	42 pound

Debris Source Term for a Loop 2 Crossover Leg Break

Debris Type	Small Pieces	Large Pieces	Total
Stainless Steel RMI	75,220 ft^2 (75%)	25,073 ft^2 (25%)	100,293 ft^2
Debris Type	**Fines**	**Large Pieces**	**Total**
Latent Fiber	6.25 ft^3	0 ft^3	6.25 ft^3
Debris Type	**Fines**	**Chips**	**Total**
Dirt/Dust	85 pound	0 pound	85 pound
Phenolic Paint	137 pound	0 pound	137 pound
IOZ Paint	1,161 pound	0 pound	1,161 pound
Alkyd Paint	44 pound	0 pound	44 pound
Epoxy Paint	25 pound	0 pound	25 pound
Carboline 295	753 pound	0 pound	753 pound
Silicone Paint	49 pound	0 pound	49 pound

Enclosure 1

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Debris Source Term for a Loop 3 Crossover Leg Break

Debris Type	Small Pieces	Large Pieces	Total
Stainless Steel RMI	63,865 ft^2 (75%)	21,288 ft^2 (25%)	85,153 ft^2
Debris Type	**Fines**	**Large Pieces**	**Total**
Latent Fiber	6.25 ft^3	0 ft^3	6.25 ft^3
Debris Type	**Fines**	**Chips**	**Total**
Dirt/Dust	85 pound	0 pound	85 pound
Phenolic Paint	149 pound	0 pound	149 pound
IOZ Paint	1,147 pound	0 pound	1,147 pound
Alkyd Paint	44 pound	0 pound	44 pound
Epoxy Paint	25 pound	0 pound	25 pound
Carboline 295	836 pound	0 pound	836 pound
Silicone Paint	48 pound	0 pound	48 pound

Debris Source Term for a Loop 4 Crossover Leg Break

Debris Type	Small Pieces	Large Pieces	Total
Stainless Steel RMI	63,483 ft^2 (75%)	21,161 ft^2 (25%)	84,644 ft^2
Debris Type	**Fines**	**Large Pieces**	**Total**
Latent Fiber	6.25 ft^3	0 ft^3	6.25 ft^3
Debris Type	**Fines**	**Chips**	**Total**
Dirt/Dust	85 pound	0 pound	85 pound
Phenolic Paint	146 pound	0 pound	146 pound
IOZ Paint	1,148 pound	0 pound	1,148 pound
Alkyd Paint	44 pound	0 pound	44 pound
Epoxy Paint	25 pound	0 pound	25 pound
Carboline 295	817 pound	0 pound	817 pound
Silicone Paint	40 pound	0 pound	40 pound

3.b.5. *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.*

TVA Response

A conservative allowance of 1,000 ft^2 was used for tapes, tags, labels, etc., inside the containment. Based on the Unit 1 containment walkdown results documented in WAT-D-11530, "WBN Unit 1, Containment Latent Debris Walkdown, Transmittal of the Final Report for Containment Latent Debris Walkdown", (LTR-CSA-06-74, Proprietary), a conservative estimate of the total surface area of all signs, placards, tags, tape and similar miscellaneous materials in containment was established as 697 ft^2 thereby confirming the adequacy of the original design allowance. Since the Unit 2 containment design (including internal systems) is essentially identical to Unit 1, the allowance is the same for Unit 2.

The entire quantity of signs, placards, tags, tape and similar miscellaneous materials was conservatively assumed to be transported to the sump intake. Based on Section 3.5.2.2.2 of the NRC SER for NEI-04-07, a 75% packing ratio was applied to this debris which resulted in a 750 ft^2 surface area blockage for design and testing.

3.c. *Debris Characteristics*

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss.

3.c.1. *Provide the assumed size distribution for each type of debris.*

TVA Response

The size distribution for the different type of debris applicable to the WBN containment buildings are as follows.

Insulation

Reflective Metal Insulation (RMI)

Generic testing of the RMI used in the WBN containment established that 71% of the affected RMI was destroyed in 1/4-inch to 2-inch pieces and 29% was destroyed in 4-inch to 6-inch pieces. Based on this data, Section 3.4.3.3.2 of NEI-04-07 recommends using a size distribution of 75% small pieces and 25% large pieces, where small pieces are defined as anything less than 4 inches. This recommendation was used to size the WBN RMI debris.

Coatings

Essentially all steel surfaces at WBN are coated with Carbozinc™ 11 (an inorganic zinc primer). Steel to an elevation of 6 feet above the containment floor has also been top coated with Phenoline™ 305. The containment liner is also coated with Carbozinc™ 11 and has been left without a topcoat. Even though failure of this Carbozinc™ 11 coating is not likely, it has been conservatively assumed to fail.

The concrete floors and walls have been painted with Phenoline™ 305. Concrete to an elevation of 6 feet above the containment floor has been painted with a Carboline™ 295 surfacer and then painted with two coats of Phenoline™ 305.

The original SGs were coated with Carboline™ 4674 underneath the RMI insulation. The original Carboline™ 4674 coating is a high temperature silicone that was not DBA qualified and was assumed to fail as fines if the RMI that encapsulates it fails.

Qualified coatings outside the coatings' ZOI will remain intact.

The sizing of the coating debris was established as follows:

Carbozinc™ 11:

The characteristic particle diameter of inorganic zinc (IOZ) was assumed to be 10 μm. Based on Table 3-3 of NEI-04-07, the density of IOZ particulate is 457 pound/ft^3.

However, the dry film bulk density of Carbozinc™ 11 is only 223 pound/ft^3. This value was derived from the liquid density and other published properties for Carbozinc™ 11.

Carboline™ 295:

The characteristic particle diameter of Carboline™ 295 was assumed to be 10 µm. A dry film bulk density of 123 pound/ft^3 was derived using published properties of Carboline™ 295. This value was also assumed to be the density of the particulate, as this value is higher than the 94 pound/ft^3 density recommended for generic epoxy/phenolic particulate in Table 3-3 of NEI 04-07.

Phenoline™ 305:

The characteristic particle diameter of Phenoline™ 305 was assumed to be 10 µm. A dry film bulk density of 105 pound/ft^3 was derived using published properties for Phenoline™ 305. This value was also assumed to be the density of the particulate, as this value is higher than the 94 pound/ft^3 density recommended for generic epoxy/phenolic particulate in Table 3-3 of NEI 04-07.

Carboline™ 4674

The characteristic particle diameter of Carboline™ 4674 was assumed to be 10 µm. Based on the CRC Handbook of Chemistry and Physics, the density of silicone particulate is 145 pound/ft^3. A dry film bulk density of 87 pound/ft^3 was derived using published properties for Carboline™ 4674.

Latent Debris

Dirt/Dust

The representative size and density of dirt/dust particulate was assumed to be 17.3 µm and 169 pound/ft^3, respectively, based on Section 3.5.2.3 of the NRC SER for NEI-04-07.

Fiber

The representative bulk density of latent fiber was assumed to be 2.4 pound/ft^3, and the material (individual fiber) density of latent fiber was assumed to be 94 pound/ft^3 based on Section 3.5.2.3 of the NRC SER for NEI-04-07. The SER does not give a characteristic latent fiber diameter, but it does indicate that it is appropriate to assume the same diameter as commercial fiberglass (7 µm for Nukon per NUREG/CR-6224). This value was used for the WBN analysis.

3.c.2. *Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris*

TVA Response

The bulk densities and material densities used to analyze fibrous and particulate debris at WBN are as follows:

Physical Properties of Particulate Debris

Debris Type/Size	Material Bulk Density	Particulate/Individual Fiber Density
Phenolic Paint (Fines)	105 pound/ft^3	105 pound/ft^3
IOZ Paint (Fines)	223 pound/ft^3	457 pound/ft^3
Alkyd Paint (Fines)	98 pound/ft^3	98 pound/ft^3
Carboline 4674 (Fines)	87 pound/ft^3	145 pound/ft^3
Carboline 295 (Fines)	123 pound/ft^3	123 pound/ft^3
Epoxy (Fines)	94 pound/ft^3	94 pound/ft^3
Dirt/Dust (Fines)	-	169 pound/ft^3
Latent Fiber (Fines)	2.4 pound/ft^3	94 pound/ft^3

3.c.3. *Provide assumed specific surface areas for fibrous and particulate debris*

TVA Response

The head loss across the current advanced design containment sump strainers was established by test rather than calculation. As such, these values are not part of the current sump strainer design basis.

3.c.4. *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

TVA Response

The debris characterization assumptions used in the WBN debris generation analysis are consistent with NEI-04-07 as modified by the NRC SER for NEI-04-07. No deviation from the guidance documents was required.

3.d. *Latent Debris*

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss.

3.d.1. *Provide the methodology used to estimate quantity and composition of latent debris.*

TVA Response

The quantity and composition of the latent debris in the WBN containment building was based on the assumptions discussed in the response to ***Item 3.d.2***. A quantitative latent debris walkdown was performed on Unit 1 to confirm that the actual latent debris was bounded by the assumed values. This walkdown was based on as-found conditions at the start of a refueling outage. The walkdown involved the collection of debris samples from 26 locations inside the containment building selected to provide a representative sample of the latent debris present in the containment building. The sample collection area for each location varied in size from 1.3 ft^2 to 104.5 ft^2. The samples collected were analyzed for both quantity and type of debris. The latent debris from the sampled areas was then projected for the entire containment building based on the total amount of surfaces similar to those surveyed. A similar confirmatory walkdown for loose debris will be performed on Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup.

3.d.2. *Provide the basis for assumptions used in the evaluation.*

TVA Response

The assumptions concerning latent debris in the WBN containment building involved: (1) latent debris types, (2) latent debris physical characteristics, and (3) total quantities of latent debris.

Consistent with the guidance provided in the NRC SER for NEI-04-07, the latent debris characteristics were assumed to be as follows:

- fiber contributes 15% of the mass of the total latent debris inventory with particulate contributing the remaining 85%;
- latent fiber material has an average density of 94 pound/ft^3;
- latent particulate material has a nominal density of 169 pound/ft^3;
- latent fiber material has an as-manufactured density (dry bed bulk density) of 2.4 pound/ft^3; and
- latent fiber has the same diameter as commercial fiberglass (7 μm for Nukon per NUREG/CR-6224).

Based on Section 3.5.2.2 of NEI-04-07, the maximum quantity of latent debris inside containment would be 200 pounds. This value was reduced by 50% to be more representative of the containment conditions while still bounding the Unit 1 walkdown results. The 100 pounds result is used for Unit 2. Of the 100 pounds, 85 pounds were assumed to be dirt/dust and the remaining 15 pounds were assumed to be fiber.

3.d.3. *Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under c. above.*

TVA Response

The latent debris walkdown on Unit 1 found small quantities of particulate debris such as dust, dirt, paint chips, wood chips, concrete chips, metal shavings, metal washers, nails, screws, wire powder, tape and miscellaneous artifacts. The quantity found projects to a total containment quantity of 69.2 pounds. Only a few latent fibers and string material were found. A 1% fiber loading was estimated from the samples which equates to approximately 0.7 pound. The latent debris survey results confirmed that the assumptions described in the response to ***Item 3.d.2.*** are conservative with respect to both the composition and the quantity of the actual latent debris in the WBN containment buildings. A similar walkdown will be performed on Unit 2 as described in the response to ***Item 3.d.1.***

3.d.4. *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

TVA Response

As discussed in the response to ***Item 3.b.5.***, a sacrificial surface area of 750 ft^2 (1000 ft^2 x 0.75 loading) has been established for latent debris in the form of signs, placards, tags, tape and similar miscellaneous materials.

3.e. ***Debris Transport***

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

3.e.1. *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.*

TVA Response

The debris transport methodology used for WBN involves the estimation of the fraction of debris that is transported from debris sources (break location) to the sump screens. The four major debris transport modes used in the WBN methodology are:

- *Blowdown transport:* the vertical and horizontal transport of debris to all areas of containment by the break jet.
- *Washdown spray transport:* the vertical (downward) transport of debris by the containment sprays and break flow.
- *Pool fill transport:* the horizontal transport of debris by break and containment spray flows from the refueling water storage tank (RWST) to areas that may be active or inactive during recirculation.
- *Recirculation transport:* the horizontal transport of debris from the active portions of the recirculation pool to the sump screen by the flow through the ECCS.

The specific effect of each mode of transport was analyzed for each type of debris generated, and a logic tree was developed to determine the total transport to the sump screens. The purpose of this approach is to break a complicated transport problem down into specific smaller problems that can be more easily analyzed.

The detailed methodology used for the WBN transport analysis is as follows:

1) A 3-dimensional model was built using computer aided drafting (CAD) software based on containment building drawings.

2) A review was made of the drawings and CAD model to determine transport flow paths. Potential upstream blockage points including screens, fences, grating, drains, etc., that could lead to water holdup were addressed.

3) Debris types and size distributions were gathered from the debris generation calculation for each postulated break location.

4) The fraction of debris blown into the ice condenser was determined based on the flow of steam during the blowdown.

5) The quantity of debris washed down by ice melt and spray flow was conservatively determined.

6) The quantity of debris transported to inactive areas or directly to the sump screens was calculated based on the volume of the inactive and sump cavities proportional to the water volume at the time this cavity was filled.

7) Using conservative assumptions, the locations of each type/size of debris at the beginning of recirculation was determined.

8) A computational fluid dynamic (CFD) model was developed to simulate the flow patterns that would occur during recirculation.

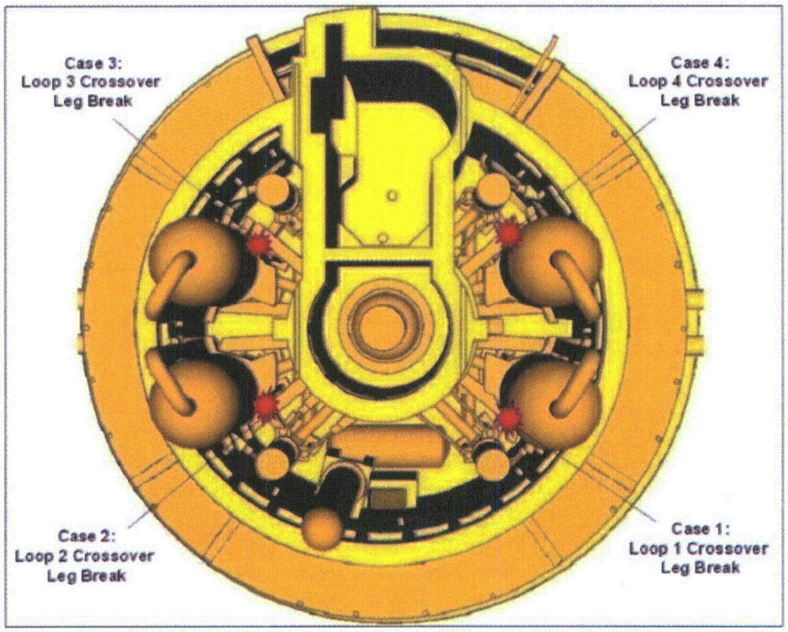
9) A graphical determination of the transport fraction of each type of debris was made using the velocity and turbulent kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.

10) The recirculation transport fractions from the CFD analysis were gathered to input into the logic trees.

11) The quantity of debris that could experience erosion due to the break flow, spray flow, or ice melt drainage was determined.

12) The overall transport fraction for each type of debris was determined by combining each of the previous steps in logic trees.

The methodology is based on NEI 04-07 for refined analyses as modified by the NRC SER for NEI-04-07, as well as the refined methodologies suggested in Appendices III, IV, and VI of the SER. The figure below represents Unit 1. Unit 2 is a mirror image of this figure.



3.e.2. *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*

TVA Response

None of the transport analysis assumptions and methods deviates from the approved guidance documents discussed in the response to ***Item 3.e.1***.

3.e.3. *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*

TVA Response

The CFD calculation for recirculation flow transport in the WBN containment building was performed using Flow-3D, Version 8.2. Flow-3D is a commercially available general-purpose computer code for modeling of dynamic behavior of liquids and gases influenced by a wide variety of physical processes. The program is based on the fundamental laws of mass, momentum and energy conservation. It has been constructed for the treatment of time-dependent multi-dimensional problems and is applicable to most flow processes. Version 8.2 of Flow-3D has been validated and verified under ALION Science and Technology's (TVA Contractor) Quality Assurance program.

The CFD model was developed to simulate the flow patterns that occur during recirculation using the following methodology:

1) The mesh in the CFD model was sized to sufficiently resolve the features of the CAD model discussed in the response to ***Item 3.e.1***.

2) The boundary conditions for the CFD model were set based on the configuration of WBN during the recirculation phase.

3) The ice melt and containment spray flows were included in the CFD calculation with the appropriate flow rate and kinetic energy to accurately model the effects on the containment pool.

4) At the postulated break location, a mass source was added to the model to introduce the appropriate flow rate and kinetic energy associated with the break flow.

5) A negative mass source was added at the sump location with a total flow rate equal to the sum of the spray flow and break flow.

6) An appropriate turbulence model was selected for the CFD calculations.

7) After running the CFD calculations, the mean kinetic energy was checked to verify that the model had been run long enough to reach steady-state conditions.

8) Transport metrics were determined based on relevant tests and calculations for each significant debris type present in the WBN containment building.

Significant assumptions used in the development of the CFD model include the following.

1) Transport calculations were performed for a break in the 31" inner diameter crossover leg at the base of the SG for each of the primary system loops. It was assumed that breaks in Loops 1 and 2 (locations on the far side of containment from the sump) would have equivalent recirculation transport fractions, and breaks in Loops 3 and 4 (locations near the sump) would have equivalent transport fractions. This is reasonable since the containment building is almost completely symmetric, which would cause the pool flow paths and velocities to be very similar during recirculation.

2) The water falling from the RCS breach was assumed to do so without encountering any structures before reaching the containment pool. This is a conservative assumption since any impact with structures would dissipate the momentum of the water and decrease the turbulent energy in the pool.

3) It was assumed that the agitation caused by the ice melt drainage as it reaches the containment pool can be conservatively introduced at the bottom of the pool. This approach is conservative since the floor is where sunken debris that could be tumbled along or re-suspended would reside. Additional studies were also performed which introduced the drainage at the surface of the pool in a more realistic fashion with less conservative results.

4) It was assumed that the small fraction of spray water that flows through the fans into the accumulator rooms is negligible in terms of affecting the pool flow (maximum design flow of 127 gpm through Room 3 and 18 gpm through Room 4). Therefore, all of the spray water was introduced through the refueling canal drains.

The debris transport fractions were determined from the CFD simulations performed for a break in the 31" inner diameter crossover leg at the base of the SG for each of the primary system loops. As described above, the transport fraction for Loops 1 and 3 were conservatively taken from the results of Loops 2 and 4 (i.e., the transport fraction for fine debris was taken from Loop 2, and the transport fraction for RMI debris was taken from Loop 4). The limiting transport fractions for all break locations are summarized as follows:

Transport Fractions of Debris to Sump Screen (Bounding Quantities)

Debris Type	Fines	Small Pieces	Large Pieces
Stainless Steel RMI*	NA	53.5%	17.9%
Phenolic Paint (inside ZOI)	100%	NA	NA
Epoxy Paint (outside ZOI)	100%	NA	NA
Inorganic Zinc Paint (inside ZOI)	100%	NA	NA
Inorganic Zinc Paint (outside ZOI)	100%	NA	NA
Modified Silicone Paint (inside ZOI)	100%	NA	NA
Modified Silicone Paint (outside ZOI)	100%	NA	NA
Alkyd Paint (outside ZOI)	100%	NA	NA
Dirt/Dust	100%	NA	NA
Latent Fiber*	100%	NA	NA

* Note an error was discovered in the method for introduction of ice melt water into the containment after the original analysis was completed. A correction to the model indicates that overall RMI transport for the worst case changed from approximately 71% total to approximately 48% total, and Fiberglass debris transport reduced from 100% to 96%. The conclusion of the corrective action review was that the original analysis remained bounding.

3.e.4. *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*

TVA Response

No credit was taken for debris interceptors in the WBN debris transport analysis.

3.e.5. *State whether fine debris was assumed to settle and provide basis for any settling credited.*

TVA Response

As part of the debris transport analysis, it was determined from these calculations that fine debris was not significantly removed from the pool.

3.e.6. *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.*

TVA Response

The overall debris transport fractions and the bounding quantities of each type of debris transported to the containment sump are as follows:

Bounding LBLOCA Debris Source Term

Debris Type	Debris Quantity	Debris Transport Fraction (DTF)	Quantity At Sump
Insulation			
RMI	101,202 ft^2 x 85,153 ft^2 x	0.48 0.71	60,458 ft^2 (1)
Fiber (no Min-k, no 3M)			
Coatings/Particulate			
Phenolic	149 pound	1.0	149 pound
IOZ	1,161 pound	1.0	1,161 pound
Alkyds	44 pound	1.0	44 pound
Epoxy Paint	25 pound	1.0	25 pound
Carboline 295	836 pound	1.0	836 pound
Silicone	49 pound	1.0	49 pound
Latent Debris			
Latent Fiber(3)	6.25 ft^3	1.0	6.25 ft^3
Dust & Dirt	85 pound	1.0	85 pound
Tags and Tape(4)	1000 ft^2	1.0	1000 ft^2

(1) The Quantity at Sump is the greater of 101,202 ft^2 x 0.48 or 85,153 ft^2 x 0.71.

(2) Not used

(3) The volume of latent fiber was calculated by dividing the mass of latent fiber by the bulk density of NUKON®as shown in NEI-04-07 (2.4 pound/ft^3). This gives a latent fiber volume of 6.25 ft^3 (15 pound/2.4 pound/ft^3).

(4) Section 3.5.2.2.2 of the SER for NEI-04-07 allows a 75% overlap of tags/tape/labels on a strainer screen. As a result, the wetted sump screen flow area was reduced by an area equivalent to 75% of this area.

The most limiting amount of each debris type was taken from each of the 4 loop cases. This table is therefore not representative of the debris quantities for any individual loop.

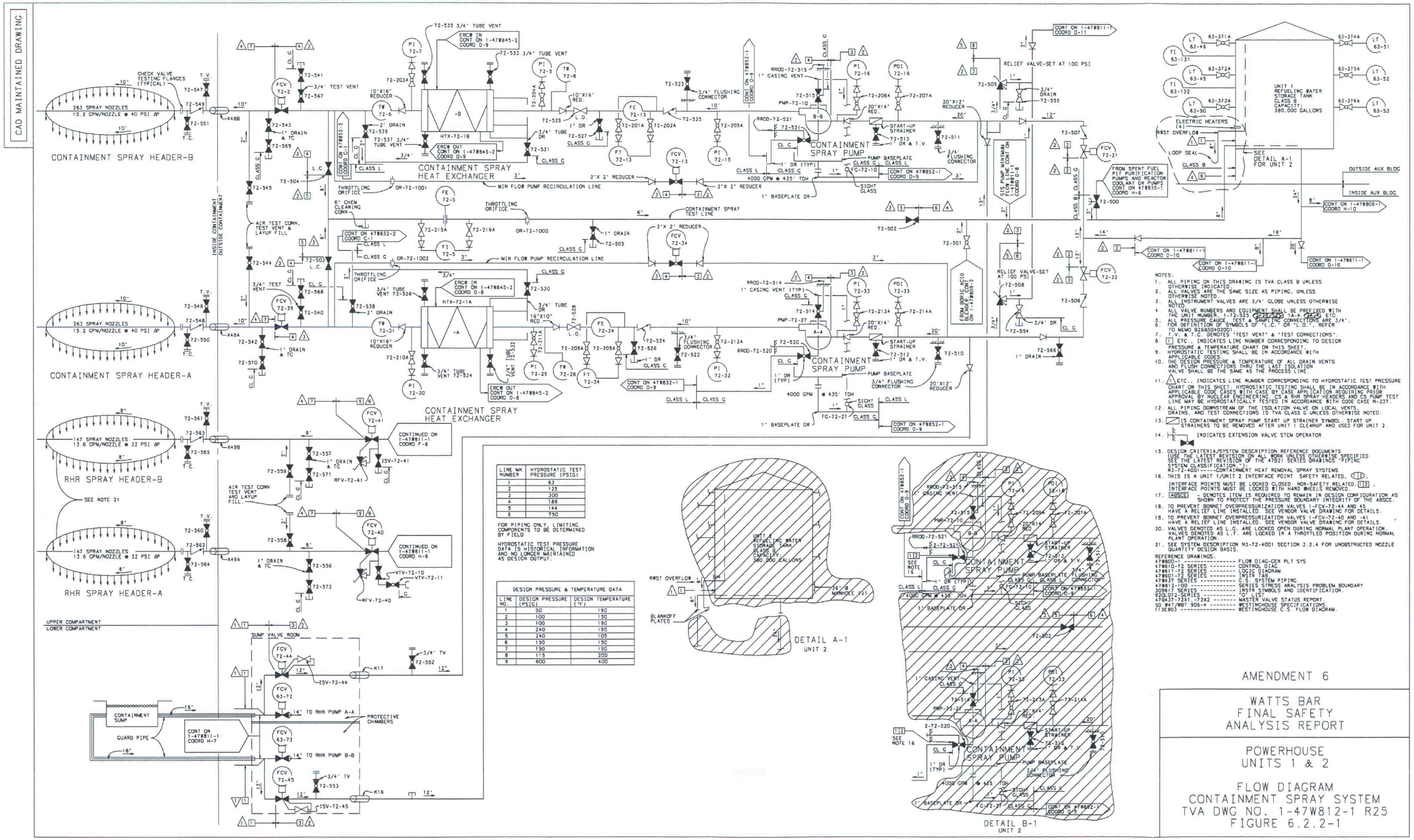
3.f. Head Loss and Vortexing

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

3.f.1. *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*

TVA Response

Figures 6.2.2-1 and 6.3-1-1 of the Unit 1 Updated Final Safety Analysis Report (UFSAR) provide schematic flow diagrams for CSS and ECCS, respectively. (Copies are provided herein for convenience.) Unit 2 design/construction is in progress but will be functionally the same as Unit 1.



LINE MK NUMBER	HYDROSTATIC TEST PRESSURE (PSIG)
1	63
2	125
3	300
4	188
5	144
6	750

FOR PIPING ONLY, LIMITING COMPONENTS TO BE DETERMINED BY FIELD

HYDROSTATIC TEST PRESSURE DATA IS HISTORICAL INFORMATION AND NO LONGER MAINTAINED AS DESIGN OUTPUT.

DESIGN PRESSURE & TEMPERATURE DATA		
LINE NO.	DESIGN PRESSURE (PSIG)	DESIGN TEMPERATURE (°F)
1	50	190
2	100	150
3	100	190
4	240	190
5	240	105
6	150	150
7	150	190
8	115	200
9	600	400

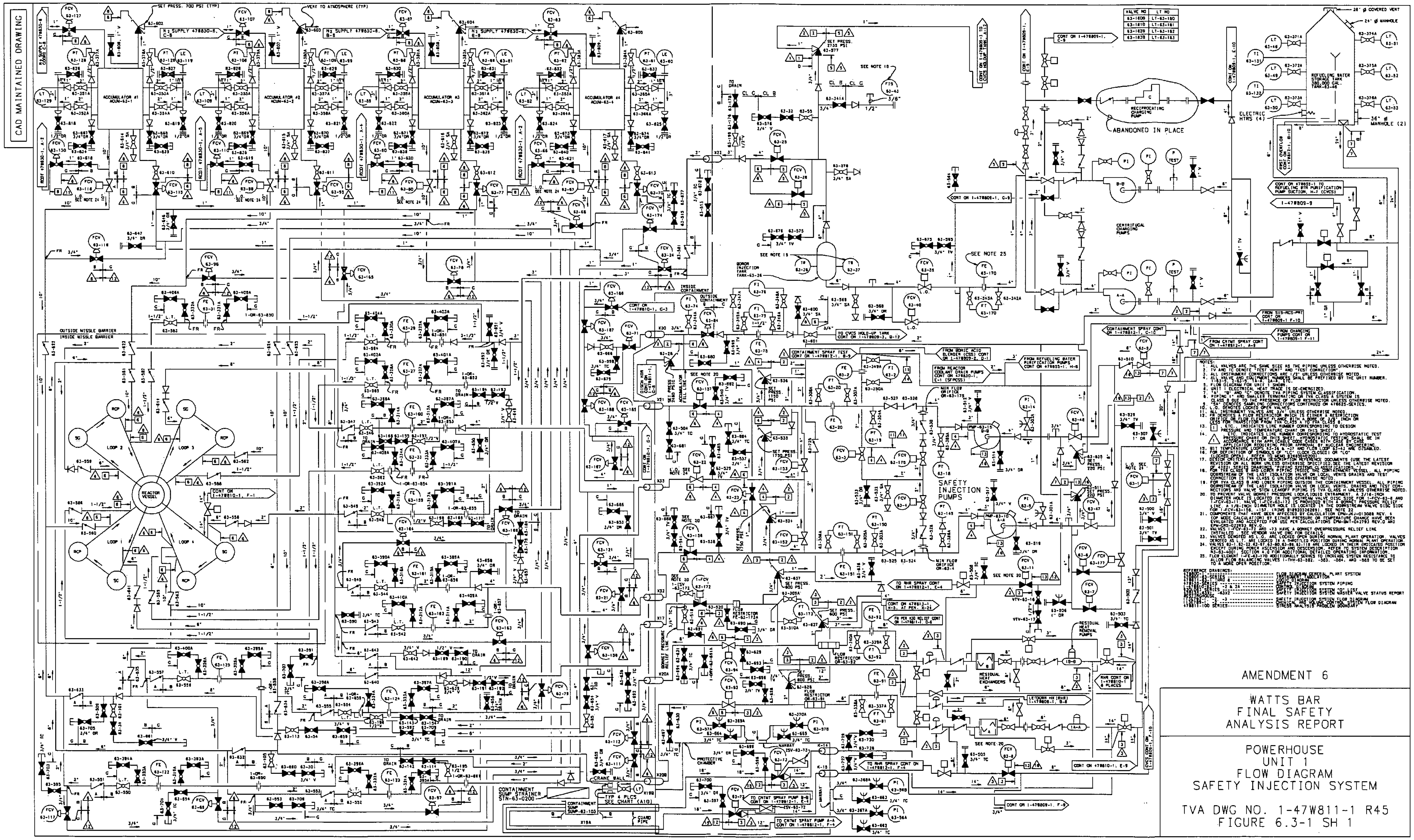
AMENDMENT 6

WATTS BAR
FINAL SAFETY
ANALYSIS REPORT

POWERHOUSE
UNITS 1 & 2

FLOW DIAGRAM
CONTAINMENT SPRAY SYSTEM
TVA DWG NO. 1-47W812-1 R25
FIGURE 6.2.2-1

Supplemental Response to Address GL 2004-02 Actions at Unit 2
Using Revised Content Guide for GL 2004-02 Supplemental Responses



3.f.2. *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*

TVA Response

The minimum submergence of the WBN containment sump strainer under LBLOCA and SBLOCA conditions occurs at the time of initial recirculation operation.

Containment Sump Strainer Minimum Submergence

Conditions	Minimum Sump Level	Strainer Assembly Height [1]	Minimum Submergence
Large Break LOCA			
ECCS Recirculation	8.51 ft	Short: 4.81 ft	3.70 ft
	8.51 ft	Tall: 5.52 ft	2.99 ft
CSS Recirculation	11.91 ft	Short: 4.81 ft	7.10 ft
	11.91 ft	Tall: 5.52 ft	6.39 ft
Small Break LOCA [2]			
ECCS Recirculation	5.78 ft	Short: 4.81 ft	0.97 ft
	5.78 ft	Tall: 5.52 ft	0.26 ft
CSS Recirculation	6.91 ft	Short: 4.81 ft	2.10 ft
	6.91 ft	Tall: 5.52 ft	1.39 ft

1 WBN strainers are of different heights as discussed in the response to ***Item 3.j.1***.

2 SBLOCA results are for the 120 gpm SBLOCA case. 2,000 gpm SBLOCA was also examined in sump water inventory calculations for NPSH.

3.f.3. *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*

TVA Response

The original WBN containment sump intake structure contained a number of design features (i.e., grating, baffle plates, and screens) that were designed to prevent vortex formation. The effectiveness of the original design to prevent vortex formation was verified through 1:4 scale testing performed prior to initial plant operation.

Modification of the sump for GL 2004-02 compliance involved the removal of the original inlet structure and replacement with advanced design strainer assemblies. As none of the other vortex suppression features shown in Unit 1 UFSAR Figure 6.3-6 were altered by the modification, the effect of the change was qualitatively determined to be neutral or to decrease the potential for vortex formation such that the original scale testing remained valid.

The potential for vortex formation in the strainer assembly was also evaluated. The WBN strainer module disks are nominally 5/8" thick with a 1" separation between adjacent disks. The interior of the disks contains rectangular wire stiffeners for support. The strainers are configured as a "sandwich" made up of three layers of wires. The disks are completely covered with perforated plate having 0.085" diameter holes. Based on this configuration, the largest opening for water into the strainer flow channel is through the 0.085" diameter holes. An air ingestion evaluation based on Froude number was performed. It was determined that the calculated Froude number was 50% of the criteria for air ingestion. It would therefore be expected that air ingestion would be less than 2%, and that vortex formation would be unlikely. A void fraction analysis was also conducted. It was determined that the void fraction would remain less than 3% at expected containment conditions even at atmospheric pressure.

For LBLOCA and SBLOCA, the WBN sump strainers remain submerged at the initiation of sump recirculation operation. Thus, vortex formation in the sump would not be expected to occur.

3.f.4. *Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.*

TVA Response

AREVA NP, Inc. (AREVA) and Alden Research Laboratory, Inc. (ALDEN) performed testing of a WBN prototypical ECCS and CSS sump strainer. Testing was conducted to determine the head loss (pressure drop) across the strainer based on the postulated debris load present in containment post LOCA. Testing was performed at ALDEN in Holden, Massachusetts, during the week of July 12, 2010, in accordance with Test Procedure 63-9138558-000 (an AREVA document). The test data was documented in Test Procedure 63-9138558-001. This testing was performed in accordance with a procedure that was found acceptable to the NRC, and this test was witnessed by the NRC.

The purpose of testing was to measure the strainer head loss (differential pressure) across the Unit 1 strainer based on prototypical strainer flow rates and debris loads expected in containment following a postulated LOCA. Testing utilized one strainer array that included four modules and a scaled debris source term. The debris load was scaled by the ratio of the surface area of the test strainer to total available strainer area installed in containment. The debris load was scaled by Performance Contracting Inc. (PCI) in the PCI document, "Debris Allocation Tables for Watts Bar Strainer Performance Testing."

The pre-weighed and wetted non-chemical debris was injected into the test tank via a trash pump to ensure the debris was thoroughly mixed and prevent debris agglomeration. Dirt and dust were introduced manually to prevent trash pump damage. Debris was placed in the test tank based on the debris size category, fine, small, large, and density, lowest to highest. This method ensured large and high density debris does not impede transport of smaller and less dense debris. A minimum of two turnovers was required before proceeding from fine to small and from small to large debris. All non-fibrous debris was added to the test tank prior to adding fibrous debris. The fibrous debris consisted of 1/16th inch bed equivalent sizes. The strainer head loss was monitored between fiber batches; subsequent batches were not added to the test tank until the change in strainer head loss was less than 1% in 30 minutes and a minimum of two test tank turnovers were completed. Batches were added until a significant increase in strainer head loss was recorded, the test tank water cleared due to an established filtering bed, or it was visually observed that the strainer was completely covered with a fiber bed. A significant increase in head loss is indicative of a thin bed fiber formation on the strainer.

The completed test procedure with testing notes is documented in Revision 1 of the test procedure, "Test Plan for Watts Bar Unit 1 ECCS Strainer Performance Testing." The test descriptions are as follows:

Test 1 – Clean Strainer Head Loss Test:

This test determined the head loss of the clean strainer in the test tank. This data is subtracted from the latter tests to determine the "debris loaded" head loss for the strainer. (Performed July 12, 2010)

Test 2 – Fiber Bypass Test (No Particulate):

This test includes fiber only to establish the transport characteristics of fibers introduced incrementally up through the maximum design fiber basis to determine the fiber bypass rate. Visual observation was performed to evaluate the formation of a fibrous debris bed. Note that debris bypass sampling was performed during this test. (Performed July 12, 2010)

Test 3 – Design Basis Debris Loaded Strainer Head Loss Test:

This test was designed to determine the debris loaded head loss for the strainer using the design basis accident debris load. This test was not performed as it was bounded by Test 4C.

Test 4, 4B, and 4C – Design Basis Debris Loaded Thin Bed Test:

This test determined if a higher head loss is possible with a thin bed of fibers, particulate, and chemical debris present, rather than with the design basis quantity of debris. This test included all particulates, chemical debris, and that fiber quantity determined to form a thin bed of fibers on the surface of the strainer. (Three of these tests were performed with each test using a revised debris load. They were performed on July 13, 2010; July 14-15, 2010; and July 16, 2010.) Test 4C debris loading is the design basis for the Unit 2 strainers. 3M insulation was included as debris for this test, but is applicable only to the Unit 1 containment.

TEST APPARATUS

The strainer tests were conducted in a tank with approximate dimensions of 6' wide x 6' high x 13' long. Accident conditions for strainer performance are simulated by recirculating debris laden water through the tank with strainer. The tank has three distinct sections: an upstream high-energy mixing section, a middle debris-suspension section, and a downstream section containing the strainer module. A pump and piping are provided on the exit of the strainer to return the water to the tank's upstream and middle sections. A portion of the strainer flow is reintroduced in the upstream high-energy mixing section of the tank, while the major portion returns through a perforated floor in the middle section of the tank.

The upstream section prevents debris settling using two variable speed pipe mixers. Each mixer is an aluminum pipe with a single rotating propeller inside it. The mixers draw flow from the top of the tank and push the flow downward towards the floor. The middle section employs a perforated floor panel that imparts an upward flow to maintain debris suspension without disturbing the debris bed that may form on the strainer. A separate chemical generation tank and a pump were used to introduce the chemical debris into the test tank.

During the test, water in the test tank was lowered prior to adding debris and chemicals to prevent exceeding the prototypical strainer submergence. Water inventory was monitored to ensure the prototypical strainer submergence was not exceeded by more than 1 inch during testing. Tank level was verified after each debris introduction and water inventory removed and filtered if required. The water removal filters were periodically cleaned to allow reintroduction of the debris trapped in the filters to the test tank.

Debris was introduced into the test tank to avoid direct impact on the strainer module to diminish any disturbance that would prevent debris from accumulating on the screen and/or drive accumulated debris off the screen. Debris was introduced through the debris injection hopper that discharged into the test tank below the water surface upstream of the mechanical pipe mixers. The test configuration included a 6" perimeter around the strainer where no additional energy was added. Settling in this area was minimal and considered conservative relative to plant conditions. Skimmer boards were placed across the test tank to retain floating debris in the high mixing energy regions to provide additional time for the turbulence to re-entrain the floating debris in the water.

Debris Preparation

Debris used in the tests was weighed dry and recorded. Debris was supplied and prepared in accordance with the PCI debris preparation white paper SFSS-TD-2007-004 prior to use and verified by the AREVA Test Engineer. Debris slurries were produced with a high dilution ratio and were introduced by trash pump with the exception of "heavy" debris types such as dirt and dust. Heavy debris types were introduced by hand via a bucket. This introduction method for heavy debris is required to ensure the trash pump does not become clogged or damaged by debris. Flotation was not a concern with dirt and dust.

Debris Mixing

All debris, except latent dirt and dust, was thoroughly wetted with warm water and mixed with a power mixer prior to introduction into the test tank.

Debris Introduction

Debris introduction by a trash pump mounted to the hopper allowed debris to be introduced gradually to the test tank alleviating concerns over non-conservative debris concentration and agglomeration. Debris introduction was just below the water surface to avoid splashing and air entrainment. Prior to adding debris, the test tank water level was lowered to account for the additional water volume being added due to the debris introduction. The level was maintained sufficiently high to ensure the debris introduction nozzles remained submerged. Between debris types, the test tank water level was adjusted to ensure the strainer submergence was maintained. The premixed debris was added to the hopper one trash drum at a time. Subsequent batches of debris were added to the hopper after the debris had been pumped out of the hopper. Dry latent dirt and dust debris was added to the test tank in the high energy mixing zone. Chemical debris was added in four batches, including the final chemical system rinse. The chemical was batched based on the total chemical volume that could be added to the tank without exceeding the required strainer submergence. Each chemical batch addition was approximately four minutes and approximately 25% of the total chemical debris load.

Water Management

During debris addition, the water level in the test tank was manually maintained via a drain line connected to the strainer discharge piping. The drain line discharge was directed to a 1 – 10 micron filter bag to retain debris being removed by the water management system. The debris retained in the filter bags was rinsed into a 5 gallon or 33 gallon bucket and returned to the test tank via the debris hopper or direct injection to the water surface of the test tank.

Test Strainer

Unit 2 contains 23 strainer arrays. The horizontal stacked disc strainer arrays are composed of three or four module assemblies. Testing utilized one four module strainer array with an area of 216.5 ft^2.

DEBRIS DESCRIPTION

The following are descriptions and introduction sequencing of the debris used in the tests. Note that no debris was used during the Clean Strainer Head Loss Test. Debris preparation and surrogate justification is documented in PCI Technical Document No. SFSS-TD-2007-004 and provides the justification for the use of coating surrogate materials.

Coating Debris

The Debris Allocation tables document the coating debris types that may exist within the Unit 2 containment. For testing, acrylic powder and tin powder (fine particulates) were used as surrogates.

Particulate Debris

The Debris Allocation tables document the particulate debris (dirt and dust) that exists within the Unit 1 containment. The PCI PWR 2 dirt mix (fine particulate) was used as the representative material.

Mixed Particulate and Fibrous Debris

The Debris Allocation tables document the mixed particulate and fibrous debris types that may exist within the Unit 1 containment. 3M I-10A and Min-K were used to represent the mixed particulate and fibrous debris within the Unit 1 containment. Note that 3M I-10A was supplied by TVA to PCI as a surrogate for 3M-M20C since 3M-M20C is no longer manufactured.

Fibrous Debris

The Debris Allocation tables document the fibrous debris types that may exist within the Unit 2 containment. Fine NUKON® fibrous debris was used as a surrogate for latent fibers.

METHODOLOGY

Clean Strainer Head Loss Test

The test strainer was evaluated using clean water to measure the clean strainer head loss over an average operating range from approximately 700 gpm to 1,100 gpm. Five flow rates were tested in total. The pressure downstream of the strainer was recorded within the strainer's discharge piping. Due to placement of the pressure taps, the recorded clean strainer head loss also included some minimal piping losses in addition to the losses across the strainer's screen.

Debris Loaded Head Loss

The head loss across the strainer was measured throughout testing. This measurement included the clean strainer head loss, as discussed above, and the head losses created by debris on the strainer's screen.

Head Loss / Limited Value

Per the NRC guidance contained in Reference 9, "Licensees should provide sufficient information for the staff to have reasonable assurance that their head loss tests have realistically or conservatively determined maximum strainer head loss over the 30-day mission time". Since the strainer testing for WBN was performed over a much shorter time than 30 days, a conservative method of predicting the head loss at the mission time is needed.

The termination criteria were met at the end of the WBN test (15 tank turnovers and a percent change of less than 1% over 30 minutes). Linear and exponential trend lines were applied to the measured head loss data over the last 15 tank turnovers. For both trend lines, the coefficient of determination (R_2) value is less than 0.05. Since the R_2 values are significantly close to zero, it is not statistically justifiable to predict the future head loss based on the trend line equation. To determine the limiting head loss value over 30 days based on the WBN test results, a limiting value was determined using a conservative statistical approach. Since a trend line cannot be justified due to low R_2 values, the upper limit average head loss is determined using the normal distribution (Gaussian distribution) probability function and the maximum deviation between the head loss mean and the measured head loss.

The sample mean and standard deviation are determined for the measured head loss population. Since WBN has a large population of measured head loss data, the normal distribution value for a 95% confidence level is 1.96 standard deviations. For additional conservatism, the absolute value of the maximum deviation between the head loss mean and the measured head loss are added to the upper limit head loss to conservatively determine the maximum upper level head loss.

Debris Loaded Head Loss Correction for Temperature

Since the approach velocity of the strainer was significantly less than 1 ft/s, the head loss correction due to temperature becomes a function primarily of viscosity. Using a table of values for the dynamic viscosity (μ) of water as a function of temperature, the value of μ for both the average measured water temperature and the specified reference temperature for the strainer's operation following a LOCA was determined. Using the ratio of the dynamic viscosities, the temperature was adjusted to the corrected head loss value(s).

The test temperature was maintained throughout the strainer test at ~120°F with slight deviations with introductions of debris. Thus, measured head losses were corrected based on a test temperature of 120°F to a design temperature of 190°F.

The temperature of test tank water was not recorded during the tests. However, water temperature was recorded when measuring the pH of test tank water. The average of the temperatures associated with pH measurements was 109°F. For conservatism, a temperature of 120°F was used as the test temperature for performing temperature corrections.

RESULTS

Test 1 – Clean Strainer Head Loss Test

The strainer showed no signs of vortex formation throughout the clean strainer test.

Test 2 – Fiber Bypass Test

Bypass samples were taken during Test 2. No thin bed was observed when fiber only was introduced.

Test 3 – Design Basis Debris Loaded Strainer Head Loss Test

As noted in the response to ***Item 3.f.4.***, this test was not performed as it was bounded by Test 4C.

Test 4 – Thin Bed Test

The maximum measured raw data head loss was 19.44 ft of water. This head loss occurred at flow rates of 929.8 gpm and 937.4 gpm. LBLOCA test strainer design basis flow rate is 924.1 gpm. The recorded head loss data displayed an increase after each debris batch was added to the tank. The strainer showed no signs of vortex formation. A thin bed was observed. A flow sweep, reducing flow to approximately 50% of design was completed to verify bore holes had not been created in the debris bed. The head loss performed as expected indicating there were no bore holes present.

Test 4B – Thin Bed Test

The debris allocation for this test removed all of the Min-K debris used during Test 4. The maximum measured raw data head loss was 11.47 ft of water. This head loss occurred at a flow rate of 948.0 gpm. The recorded head loss data displayed a gradual increase as the particulate batches and first three fiber batches were introduced. After the fourth fiber batch was introduced, the recorded head loss data displayed a larger increase. After the chemical batches were introduced, the measured head loss reached 11.47 ft of water. The strainer showed no signs of vortex formation. A thin bed was observed.

Test 4C – Thin Bed Test

The debris allocation for this test removed all Min-K debris, half of the latent dirt and dust particulate, and half of the NUKON® fine fibers from Test 4. After performing a statistical analysis, the upper limit head loss was 5.76 ft of water. The strainer showed no signs of vortex formation. A thin bed was observed. The recorded head loss data displayed an increase after the fourth and fifth fiber batches were introduced. The head loss slightly increased after the chemical batches were introduced. After performing a statistical analysis, the thin bed debris loaded head loss is 1.88 ft of water (clean strainer removed). The temperature corrected debris loaded head loss is 1.09 ft of water. The flow rate and water level were reduced to SBLOCA conditions, and no vortexing was observed. A flow sweep, reducing flow to approximately 50% of design, was completed to verify bore holes were not present. The head loss performed as expected indicating there were no bore holes. This test matched the design basis conditions and established the design basis performance for the strainers.

3.f.5. *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*

TVA Response

For the design basis debris load, the volume of debris was determined to be less than the maximum volume of debris that the WBN containment sump strainers could accommodate. Based on this result, the total design basis debris load was conservatively assumed to be deposited on the sump strainer assemblies. The weight of the total debris load was calculated from this volume of material to establish the maximum debris dead weight acting on the strainer assemblies. The maximum dead weight load was included in the structural analysis of the strainer assemblies

The ability of the strainer assemblies to accommodate the post-accident debris volume in terms of head loss was established by testing as discussed in the response to ***Item 3.f.4***.

3.f.6. *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.*

TVA Response

The WBN advanced design containment sump strainers were designed to preclude design basis strainer loading for post-accident sump recirculation operation. Based on containment building walkdowns performed for Unit 1, the principal source of fibrous material debris available for transport to the containment sump for Unit 2 is latent debris since Unit 2 does not use either the Min-k or 3M materials.

Unit 2 plant conditions are such that design basis strainer loading is unlikely (i.e., large strainer area, advanced strainer design, low fiber, principally RMI insulation, a deep water pool, with debris predominantly in the form of fines), the analysis of thin bed effects was performed primarily to establish the minimum flow area criteria to prevent design basis strainer loading. The final sump strainer flow area (4,600 ft^2) was selected such that design basis strainer loading is not expected to occur.

To confirm this design objective, additional tests were conducted in July 2010 on the Unit 1 strainer configurations. These tests further evaluated the performance of the advanced strainer design. A Design Basis Debris Loaded Thin Bed Test was performed that introduced Unit 1 3M materials that are not used in Unit 2. The test sequence was as follows:

Fine Particulate Debris

Batch 1: 100% of Acrylic powder: 61.5 lbm (two containers, one 30 lbm and one 31.5 lbm)

Batch 2: 100% of PWR dirt mix: 4.2 lbm

Batch 3: 100% of Tin powder: 61.8 lbm (two containers: one 30 lbm and one 31.8 lbm)

Mixed Particulate and Fibrous Debris

Batch 4-6: 3M I-10A shredded insulation: 33 lbm (six containers of 5.5 lbm each)

Fibrous Debris

Batch 7-8: NUKON® fine fibers: 0.80 lbm (0.40 lbm each batch)

Chemical Precipitate Debris

Aluminum Oxyhydroxide (AlOOH) was introduced to the test tank after all particulate and fibrous debris was placed in the tank. AlOOH was introduced to the test tank over a 44 minute period. The batch sizes were limited based on the water level increase in the test tank. Four batches consisting of approximately ~25% of the total chemical debris load were added to the test tank.

Chemical batches were separated by a minimum of three test tank turnovers (~10 minutes) to allow sufficient time for the chemical to transport to the strainer prior to adding the next batch. After all chemical batches were introduced into the test tank, the water level needed to be reduced to maintain the proper strainer submergence. Water that was drained from the test tank passed through a 1 – 10 micron bag filter. The debris that collected in the filter bag was collected in a 33 gallon drum and reintroduced into the test tank.

Per the NRC guidance contained in Reference 9, "Licensees should provide sufficient information for the staff to have reasonable assurance that their head loss tests have realistically or conservatively determined maximum strainer head loss over the 30-day mission time." Since the strainer testing for WBN was performed over a much shorter time than 30 days, a conservative method of predicting the head loss at the mission time is needed. The termination criteria were met at the end of the WBN test (15 tank turnovers and a percent change of less than 1% over 30 minutes).

The recorded head loss data displayed an increase after the fourth and fifth fiber batches were introduced. The head loss slightly increased after the chemical batches were introduced. After performing a statistical analysis, the thin bed debris loaded head loss is 1.88 ft of water. The temperature corrected debris loaded head loss is 1.09 ft of water. The flow rate and water level were reduced to SBLOCA conditions and no vortexing was observed. A flow sweep, reducing flow to approximately 50% of design, was completed to verify bore holes were not present. The head loss performed as expected, indicating there were no bore holes.

3.f.7. Provide the basis for the strainer design maximum head loss.

TVA Response

The head loss across the clean strainers and the associated flow plenum was established by calculation for the WBN ECCS and CSS service conditions. The limiting measured debris head loss discussed in the response to ***Item 3.f.4.*** was adjusted for dynamic viscosity temperature effects between the test temperature and the post-accident sump temperature. The maximum expected head loss across the advanced design strainer was established by adding the limiting case debris blockage head loss to the calculated clean strainer/flow plenum head loss. This final value was established as the WBN strainer design maximum head loss.

3.f.8. Describe significant margins and conservatisms used in the head loss and vortexing calculations.

TVA Response

The significant conservatisms used in the WBN head loss and vortexing calculations used to establish strainer assembly design margins are as follows:

a. Clean strainer head loss values established from prototype test data were increased by 6% to bound test measurement uncertainties.
b. Clean strainer flow plenum head loss values calculated using standard hydraulic flow resistance equations were conservatively increased by 10%.
c. The various size strainer assemblies have varying clean strainer head loss values. The largest strainer assembly clean head loss value was applied to the design basis head loss calculation.
d. The total debris head loss was established using the limiting measured head loss value. This value was produced by a conservative debris load (see description of the test in the response to ***Item 3.f.4.***).

3.f.9. Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.

TVA Response

The WBN clean strainer head loss calculation methodology involved establishment of individual head loss values for: (1) the strainer assemblies and (2) the strainer discharge flow plenum.

Head loss across the strainer assemblies was calculated using prototype strainer head loss test data applicable to the WBN strainers. This result was then adjusted to address: (1) measurement uncertainties associated with the prototype testing and (2) configuration differences between the prototype test strainer configuration and the WBN strainer configuration. Prototype testing performed by the strainer vendor established an empirical relationship for clean strainer head loss as a function of (1) the kinematic viscosity of water (a function of water temperature) and (2) the strainer exit velocity (a function of strainer flow rate and exit area). This equation was used to establish the "Clean Strainer Test" head losses summarized in the Table below. A maximum test measurement uncertainty of 6% was then applied to this result to bound any measurement error associated with the prototype testing equipment. This value is recorded as the "6% Test Uncertainty Correction" in the table below. Key features of the prototype test assembly were then reviewed relative to the WBN strainer assemblies for potential correction. These features included: (1) internal strainer core tube diameter and exit velocity, (2) strainer disk dimensions, (3) strainer perforation configuration, and (4) strainer length dimensions.

The head loss across the strainer collection plenum into the sump was calculated using standard hydraulic head loss equations. Head losses were calculated for: (1) the strainer discharge flow entering the plenum and (2) the plenum discharge into the sump. The strainer plenum head losses were calculated using a standard head loss equation for water exiting a pipe. The equation establishes head loss as a function of water velocity. The results of this relationship were then conservatively increased by 10% to establish bounding values. The sump pit entrance head losses were calculated using a standard head loss equation for water entering a reservoir. The equation also establishes head loss as a function of water velocity. The results of this relationship were then conservatively increased by 10% to establish bounding values.

The methodology described above for the clean strainer head loss calculation did not involve any significant assumptions.

The individual head loss results for the strainer assemblies and the collection plenum were summed to obtain the head losses for the strainer/plenum assemblies. The results of the clean strainer head loss calculations are as follows:

WBN Clean Containment Sump Strainer
Head Loss Summary

Head Loss Parameter	Unit 2
Strainer Assembly	
Uncorrected Clean Strainer Test	0.063 ft
6% Test Uncertainty Correction	0.003 ft
Flow, Perforated Plate	0.000 ft
Strainer Length	0.000 ft
Discharge Flow Plenum	
Strainer Discharge to Plenum (+10%)	0.070 ft
Plenum (+10%)	0.0064 ft

Water Entering Sump Pit (+10%)	0.195 ft
Disk Disk Internal Flow Resistance	 0.000 ft
Total Strainer Head Loss	**0.338 ft**

Based on these results, a limiting clean strainer head loss value of 0.338 ft was established for the Unit 2 strainer assemblies.

3.f.10. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*

TVA Response

The Unit 2 debris laden strainer head loss calculation methodology involved application of the limiting debris head loss value established by the testing described in the response to ***Item 3.f.4.*** to the limiting clean strainer head loss value established as described in the response to ***Item 3.f.9***. The limiting measured debris head loss value was adjusted to account for dynamic viscosity temperature effects between the test temperature and the post-accident sump temperature as discussed in the response to ***Item 3.f.13***.

The methodology described above for the debris laden strainer head loss calculation did not involve any significant assumptions.

The results of the debris laden strainer head loss calculations based on original Unit 1 testing are as follows:

Unit 2 Debris Laden Containment Sump Strainer Head Loss Summary

Head Loss Parameter	Unit 2
Clean Strainer Head Loss	0.338 ft
Strainer Debris Laden Head Loss (Tested) with Temperature Correction for Post-LOCA Temperatures Applied	1.09 ft
Total Strainer Head Loss	**1.428 ft**

Based on these results, a limiting debris laden head loss value of 1.428 ft was established for the Unit 2 strainer assemblies.

3.f.11. *State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer.*

TVA Response

The sump strainers remain submerged for all accident scenarios. Refer to the response to ***Item 3.f.2.*** for submergence data.

3.f.12. *A description of the scaling analysis used to justify near-field credit.*

TVA Response

Near-field settling was not credited as a debris reduction mechanism for the head loss testing performed for WBN. The Test Tank used for the testing described in the response to ***Item 3.f.4.*** was designed to keep debris suspended and does not credit near field debris settling. Observation of the Unit 1 strainer testing showed that test tank mixing prevented near field-settling.

3.f.13. *State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.*

TVA Response

For WBN, temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. The head loss resulting from flow through a fiber-particulate debris bed at the approach velocities of the WBN advanced design strainers (i.e., 0.014 ft/s) is 100% viscous flow (as opposed to inertial flow). As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. To adjust the measured head loss across the debris bed under test conditions, the ratio of dynamic viscosities for the warmer post-accident water temperature to the colder test water temperature was applied to the measured head loss to correct the measured value to the expected head loss under post-accident operating temperatures.

Given that the measured WBN head losses due to debris loading were (1) relatively small when compared to the calculated clean strainer/flow plenum head losses, and (2) do not vary significantly with significant changes in the tested debris quantities, no other effects or scaling considerations were applied to the head loss results.

3.f.14. *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

TVA Response

Containment accident pressure was not credited in evaluating flashing across the strainer surface (atmospheric pressure assumed).

3.g. Net Positive Suction Head (NPSH)

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a loss-of-coolant accident (LOCA) considering a spectrum of break sizes.

3.g.1. *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*

TVA Response

The pump flow rates (per train) used in the WBN sump recirculation NPSH calculation are as follows.

ECCS and CSS Flows Rates for Sump Recirculation NPSH Calculation

	Large Break LOCA (gpm)	Small Break LOCA (gpm)
CSS	4,600	4,600
ECCS (Residual Heat Removal)	5,000	5,000
Total Recirculation Flow	**9,600**	**9,600**

The sump recirculation inventory temperature used in the WBN NPSH analysis is a constant 190°F, which represents maximum post-accident sump temperature.

The minimum containment sump water levels used in the analysis are the same as those summarized in the response to ***Item 3.f.2***.

3.g.2. *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*

TVA Response

No significant assumptions were used in the calculation of the flow parameters listed in the response to ***Item 3.g.1***. Where necessary, conservative modeling techniques and design inputs were used to provide bounding results. These inputs and modeling techniques include:

1) Both trains of CSS and RHR (within the computational model) will be in operation since the suction lines from the containment sump to the RHR pumps are totally independent.
2) The containment sump fluid is at the design temperature of 190°F.
3) The pressure in containment will be at 0 psig.
4) For SBLOCA, the level at the time of RHR switchover in the containment sump following a SBLOCA will be used.

5) For SBLOCA, each train of RHR receives a flow of 5,000 gpm. This assumption is very conservative since, for most of the smaller breaks, the RHR pumps are not capable of pumping into the RCS. Therefore the highest flow that could be expected would be the total runout flow of both trains of the centrifugal charging (CCP) and safety injection (SIP) pumps (approximately 2400 gpm) when being supplied by one train of RHR (no RHR flow is discharging directly into the RCS.
6) The maximum calculated CSS flow from the sump for each train (4,600 gpm) will be assumed.

The assumptions used to establish the minimum containment sump water levels used in the analysis are summarized in the response to ***Item 3.g.9***.

3.g.3. *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*

TVA Response

The required NPSH values were obtained from vendor requirements specific to the WBN ECCS and CSS pumps. The values were based on factory NPSH testing which was performed by the pump vendors in accordance with the industry standards in place at the time of original equipment manufacture. The 3% head drop criterion was typically used for this type testing.

3.g.4. *Describe how friction and other flow losses are accounted for.*

TVA Response

Suction piping line losses (which include entrance losses and frictional losses through pipe, valves and fittings) for the ECCS and CSS pump suction piping were quantified using a computer flow simulation model which establishes gauge pressure for each point within the model. Input parameters which conservatively maximize flow through the piping were then applied to the model to establish the bounding friction losses used in the NPSH analysis.

3.g.5. *Describe the system response scenarios for LBLOCA and SBLOCAs.*

3.g.6. *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*

TVA Response (items 3.g.5. & 3.g.6.)

In response to a LOCA, the RHR, CCP, and SIP pumps automatically start upon receipt of a safety injection signal. These pumps initially inject borated water from the refueling water storage tank (RWST) to the primary system cold legs. This mode of operation is referred to as the ECCS injection mode of operation. The CSS pumps start automatically when the containment pressure reaches the high setpoint for CSS actuation. The CSS pumps also initially take suction from the RWST.

When the water level in the RWST reaches a low level setpoint (coincident with a containment water level [sump] level above the high level setpoint), switchover to the ECCS recirculation mode of operation occurs. Switchover to the recirculation mode is a semi-automatic process which involves the following.

- The containment sump isolation valves automatically open, and the RHR pump block valves in the suction piping from the RWST automatically close when the RWST level reaches the low level setpoint.
- Manual operator action is taken to (1) terminate CSS pump operation prior to a RWST low-low level setpoint; (2) perform the valve realignments required to provide suction to the CCP and SIP pumps from the discharge of the RHR pumps; (3) isolate the CCP and SIP suction piping from the RWST; (4) isolate the CSS pump suction from the RWST; (5) open the CSS pump suction to the containment sump; and (6) restart the CSS pumps.

After the ECCS recirculation operating mode is established, the RHR pumps inject to the primary system cold legs and supply water to the suction of the CCP and SIP pumps. The CCP and SIP pumps continue to inject to the primary system cold legs. This configuration is referred to as the ECCS cold leg recirculation operating mode.

If the containment building pressure exceeds an established high value and more than one hour has elapsed since the start of the event, one train of RHR may be directed to the containment RHR spray headers to assist containment pressure control. This alignment is established by manual operator action. After the containment building pressure has decreased to an allowable value, the RHR pump discharge is realigned to the primary system hot legs by manual operator action.

At a time in the event analyzed to prevent boron precipitation in the reactor vessel, recirculation flow to the primary system hot legs is established. For Unit 1, this is approximately 3 hours after the event due to the higher boron requirements for the tritium producing burnable absorber rod program. (Although the Unit 2 license will not include tritium production, the boron values have been kept the same to reduce potential for errors between units; therefore, the switchover time will be the same.) At this point, for hot leg SI recirculation, the SIP pumps are realigned by manual operator action to inject to the primary system hot legs rather than the cold legs. One RHR pump may also be realigned to supply flow to two loop hot legs. The CCP pumps continue to provide flow to the primary system cold legs. This configuration is referred to as the ECCS hot leg recirculation operating mode.

The significant differences between the response to a large break LOCA (LBLOCA) and a small break LOCA (SBLOCA) are as follow:

- Depending on the size of the break, primary system pressure may stabilize at a value that does not allow injection from the RHR pumps and the SIP pumps.
- In an SBLOCA scenario, the containment accident pressure may remain below the actuation setpoint for CSS.
- In the SBLOCA scenario, drawdown of the RWST inventory may be sufficiently low such that the safe shutdown condition is reached before the RWST low level setpoint for ECCS switchover is reached.

- The quantity of debris generated in the SBLOCA scenario is a fraction of the total design basis debris used to evaluate containment sump strainer performance.

3.g.7. *Describe the single failure assumptions relevant to pump operation and sump performance.*

TVA Response

The limiting single failure assumption for those transients which require containment sump recirculation operation at WBN (i.e., LBLOCA and SBLOCA) is the complete loss of one train of ECCS equipment.

3.g.8. *Describe how the containment sump water level is determined.*

TVA Response

The containment sump water level was established by comparison of the sump and lower containment volumes which are available to collect water for recirculation to the minimum volume of water discharged during the event reduced by the volume which is unavailable to the sump/lower containment.

The sump and lower containment volumes available to collect recirculation inventory was established by calculation of the available free volume in the areas which communicate with the event discharge sources and the recirculation sump intake.

Discharge sources for the sump recirculation inventory were based on the nature of the event and the safety system responses. The sources include: (1) primary system inventory, (2) cold leg accumulator inventory, (3) RWST inventory, and (4) ice condenser ice melt inventory.

Discharge volumes which were unavailable to the sump recirculation volume include: (1) water held up in the reactor cavity, (2) water held up on the operating deck floor, (3) water in the upper containment atmosphere, (4) refueling canal holdup, (5) water in the containment spray piping, and (6) pocket sump holdup. Additionally, for the LBLOCA at the time of CSS pump recirculation initiation, water (above the 367,000 gallons in the containment sump) will spill from inside the crane wall through unsealed penetrations into the raceway at 716' elevation where it is unavailable for future recirculation. No spill occurs for the LBLOCA or SBLOCA at the time of ECCS recirculation initiation.

3.g.9. *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*

TVA Response

The significant assumptions included in the containment sump level analysis to ensure that a minimum water level is applied to the ECCS and CSS pump NPSH evaluation are as follows:

Assumptions Applicable to the Minimum Level for an LBLOCA

(1) The maximum flow rates for two trains of ECCS and CSS pump flow are assumed for the pumps taking suction from the RWST during the injection phase. The amount of water in the sump at any given time will come from a combination of (1) RWST water, (2) water from the primary system, (3) accumulator discharge, and (4) ice melt. The primary system and accumulator water volumes are independent of the number of operating trains of ECCS / CSS pumps. If only one train of ECCS and CSS is operating, the time to deplete the RWST will be longer than for the two train case. In both cases, the total volume of water discharged at the time the RWST water is depleted will be the same. With the extended depletion time in the single train case, more ice will be melted by the time the RWST empties. Therefore, at the time the RWST empties, more water will have accumulated in the sump for the one train case than for the two train case. Using maximum flow rates (as opposed to nominal or minimum guaranteed flow rates) for the pumps will provide the shortest depletion time of the RWST which further limits the amount of ice melt available when sump recirculation is initiated. The maximum flow rates in combination with operation of two trains of ECCS and CSS minimizes the amount of water in the sump at both the low level switchover setpoint and the low-low level CSS realignment setpoint in the RWST.

(2) The initial water level in the RWST was the “minimum full” level and was conservatively chosen to minimize the water delivered to the containment sump thereby minimizing the water level in the containment sump.

(3) Water droplets from the containment spray will remain constant in size. The amount of CSS water suspended in the atmosphere is dependent on the droplet size. The smaller drops conservatively increase the amount of suspended CSS water.

(4) A reduction in the lower containment volume to account for equipment and structures in the lower containment is included in the calculation. This allowance is not used for the sump pocket, the refueling canal, or the reactor cavity since they do not contain equipment.

(5) All CSS flow falling onto the reactor enclosure in the upper compartment is assumed to flow to the operating deck prior to entering the refueling canal. This is a simplifying assumption which is conservative since it maximizes the water volume held up on the operating deck by increasing the height of water (and thereby the holdup) required to provide a flow into the refueling canal equal to the containment spray rate that falls on the floor.

Assumptions Applicable to the Minimum Level for SBLOCA

(1) The SBLOCA must be evaluated for two possible scenarios regarding minimum containment sump elevations: (1) a very small break assumed at 120 gpm to be slightly above the definition of a LOCA, and (2) a more typical SBLOCA of 2,000 gpm. Consideration of both scenarios will ensure that the minimum level is calculated.

(2) Limited credit is taken for water from melted ice. Any break that does not activate the containment spray may release an amount of energy within the capacity of the lower compartment coolers. Breaks in this size range will melt very little ice.

(3) The break is assumed to be located such that break flow is directed to the reactor cavity. This minimizes water in the containment sump.

(4) No credit is taken for water from the cold leg accumulators. The break may be too small to allow the primary system pressure to reach the accumulator dump setpoint.

(5) Because of the small break size possible, the only credit taken for primary system inventory discharge is the SBLOCA flow rate.

3.g.10. *Describe whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*

TVA Response

The volumes for empty spray pipe, water droplets, condensation, and holdup on horizontal and vertical surfaces have been accounted for in the WBN pool level calculations as follows:

Empty Spray Pipe: The volume of the containment spray pipe and header that is empty during normal operation was calculated.

Water Droplets: The volume of water suspended between the spray header exit and the operating deck/ refueling canal was calculated for steady state conditions, and is a function of: (1) CSS spray flow, (2) fall distance, and (3) vertical droplet velocity. The vertical droplet velocity was established as a function of droplet size (mass) and the drag force exerted on the droplet due to the resistance of the upper compartment atmosphere.

Condensation: Mass and energy released from the primary system in the form of steam was condensed by the ice condenser and was included in the sump discharge volume used to establish sump level. No credit was taken for condensation on other lower containment structures.

Horizontal and Vertical Surface Holdup: The volume of water suspended in horizontal or on vertical surfaces was accounted for and subtracted from the sump discharge volume as follows:

- Reactor Cavity Volume: The reactor cavity volume was assumed to fill initially as a result of the high energy line break.

- Operating Deck: Water will accumulate on the operating deck, SG enclosure roof, and pressurizer enclosure roof before draining into the refueling canal. The curbing surrounding the operating deck and pressurizer enclosure roof acts similar to a weir. The SGs do not have the curb over approximately 25% length. The water accumulation on the operating deck and enclosure roofs was calculated for the curb height under equilibrium conditions (i.e., flow onto the surface equals the flow off the surface into the refueling canal) using relationships developed for a rectangular weir.

- Refueling Canal: During CSS operation, water falling on the upper containment surfaces will collect in the refueling canal prior to draining to the lower containment sump through two 14" diameter drains in the canal. Water will collect in the canal until the drain flow out of the canal is equal to equal the containment spray flow. The level of water suspended in the canal was calculated for equilibrium conditions as function of: (1) canal drain flow resistance, (2) canal level (i.e., driving head though the drains), and (3) containment spray flow rate. The volume of water suspended in the refueling canal was established from the equilibrium level of water held up in the canal.

- Accumulator Rooms: During operation of the containment air return fans, the upper containment atmosphere is recirculated to the lower containment through Accumulator Rooms 3 and 4 (which are located outside the crane wall). Since the upper containment atmosphere contains suspended droplets of containment spray, a portion of the containment spray will be directed to the accumulator rooms by the air return fans, where the inventory will drain back inside the polar crane wall for sump recirculation. The impact of this flow was evaluated.

3.g.11. *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*

TVA Response

The volume of the major equipment and structures which have the potential to be submerged during sump recirculation operations was established by calculation. The equipment included in this volume calculation included primary system piping, primary system piping supports, the reactor coolant pumps and RHR system piping.

3.g.12. *Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.*

TVA Response

Water sources for the sump recirculation pool inventory are based on the nature of the event and the safety system responses. The sources include: (1) primary system inventory, (2) cold leg accumulator inventory, (3) RWST inventory, and (4) ice condenser ice melt inventory. The volumes of water credited from these sources in the WBN minimum containment sump level calculation were established as follows:

1) Primary System Inventory: For a LBLOCA, it is assumed that the primary system inventory will drain to approximately the bottom of the reactor vessel nozzles. The primary system inventory was established by subtracting the volume in the reactor vessel below the reactor nozzles (less the volume of the reactor core and vessel internals) from the nominal primary system operating volume. For a SBLOCA, only the leakage flow until switchover is considered for the primary system inventory.

2) Cold Leg Accumulator Inventory: For a LBLOCA, it is assumed that the cold leg accumulator volume is equal to the minimum contained volume for operability for 3 of 4 accumulators. For a SBLOCA, no credit is taken for the volume of the accumulators.

3) RWST Inventory: For both the LBLOCA and the SBLOCA, the RWST inventory is established by subtracting the retained volume at the low-low CSS pump shut-off setpoint from the initial value which is assumed to be equal to the minimum contained volume for operability.

4) Ice Melt Inventory : For a LBLOCA, the ice melt inventory is established by determining the amount of ice melted from the long term containment integrity analysis at the earliest sump recirculation initiation time (i.e., when the RWST low level setpoints are reached). The earliest sump recirculation time is based on the quickest RWST drawdown time (which occurs with two trains of ECCS and CSS pumps in service). Application of the minimum sump recirculation initiation time minimizes the amount of ice melted and the contribution of the ice melt to sump level. For a SBLOCA, limited credit is taken for ice melt inventory.

The volume of water from each of the sources used in the sump minimum level calculation is as follows:

Sump Recirculation Pool Source Inventory Summary (RHR switchover)

	LBLOCA (gallons)	SBLOCA - 2,000 gpm (gallons)	SBLOCA - 120 gpm (gallons)
Primary System Inventory	50,500	0	0
Cold Leg Accumulator Inventory	22,900	0	0
RWST Inventory to ECCS switchover	202,000	202,575	202,575
Ice Melt Inventory	147,240	46,516	3,048
Total	**422,640**	**249,091**	**205,623**

3.g.13. *If credit is taken for containment accident pressure in determining available NPSH, provide description of the calculation of containment accident pressure used in determining the available NPSH.*

TVA Response

No credit is taken for containment accident pressure in determining the available NPSH for sump recirculation operation for WBN.

3.g.14. *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*

TVA Response

The WBN containment sump NPSH calculations assume that containment pressure remains at the minimum internal building pressure of 14.3 psia. The calculations also assume that the sump recirculation inventory temperature is a constant 190°F. This value represents maximum post-accident sump temperature as established by the plant long term containment integrity analysis.

3.g.15. *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*

TVA Response

The WBN containment sump operation NPSH calculations assume that containment pressure remains at a minimum building pressure of 14.3 psia. The vapor pressure of the sump inventory corresponds to the vapor pressure of the maximum sump liquid temperature (i.e., 9.34 psia for a temperature of 190°F).

3.g.16. *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

TVA Response

The most limiting case is used for NPSH margin:

Excess NPSH for Containment Sump Recirculation Operation at RHR Switchover:

RHR system: 10.5 ft CS system: 4.8 ft

Excess NPSH for Containment Sump Recirculation Operation at CS Switchover:

RHR system: 14.2 ft CS system: 8.5 ft

3.h. Coatings Evaluation

The objective of the coatings evaluation section is to determine the plant-specific ZOI and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

3.h.1. *Provide a summary of type(s) of coating systems used in containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.*

TVA Response

As described in the response to ***Item 3.c.1.***, essentially all steel surfaces at WBN are coated with Carbozinc™ 11 (an inorganic zinc primer). Steel to an elevation of 6 feet above the containment floor has also been top coated with Phenoline™ 305. The containment liner is also coated with Carbozinc™ 11 and has been left without a topcoat. Even though failure of this coating is not likely, it has been conservatively assumed to fail. The concrete floors and walls have been painted with Phenoline™ 305. Concrete in the lower compartment has been painted with a Carboline™ 295 surfacer and then painted with two coats of Phenoline™ 305 to an elevation of 6 feet above the containment floor. The original SGs were coated with Carboline™ 4674 underneath the RMI insulation. The original Carboline™ 4674 coating is a high temperature silicone that was not DBA qualified and was assumed to fail as fines if the RMI that encapsulates it fails. Qualified coatings outside the coatings' ZOI will remain intact.

3.h.2. *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*

TVA Response

The significant assumptions included in the post-LOCA debris transport analysis and the bases for those assumptions are as follow:

General Assumptions

1) It was assumed that ¼-inch to 4-inch pieces of RMI debris can be conservatively treated as ½-inch pieces, and 4-inch to 6-inch pieces can be conservatively treated as 2-inch pieces for transport purposes. This is a conservative assumption designed to maximize transport based on size.

2) It was assumed that the settling velocity of fine debris (dirt/dust and paint particulate) can be calculated using Stokes' Law. This is a reasonable assumption since the particulate debris is generally spherical and would settle slowly (within the applicability of Stokes' Law).

3) It was conservatively assumed that the transportable miscellaneous debris addressed in the debris generation calculation including tags, labels, etc., as well as debris trapped in the ice condenser, would be transported to the emergency sump during recirculation. This is a conservative assumption designed to maximize this debris type at the sump strainers.

Debris Transport Logic Tree Assumptions

4) It was assumed that all fines generated by the LOCA would be blown upward into the ice condenser. This is a reasonable assumption since the plant is designed to relieve steam from the blowdown into the ice condenser, and fine debris generated by the LOCA would be easily entrained and carried with the blowdown flow.

5) The small and large piece debris (RMI) was assumed to fall to the floor of containment. In reality, some of the RMI debris would likely be blown into the ice condenser. However, since RMI pieces would not transport as easily as fine debris (around corners, past equipment, etc.), it would be difficult to accurately determine the blowdown transport fraction. In order to analyze the transport of RMI, a conservative initial distribution of the RMI at the beginning of recirculation was used.

6) It was conservatively assumed that all debris blown upward would be trapped by the ice baskets and subsequently washed back down with the melting ice flow.

7) During pool fill-up, it was conservatively assumed that a fraction of the fine debris would be transported directly to the sump strainer as the sump cavity fills with water. This fraction was determined based on the ratio of the sump cavity to the pool volume at the point where the sump cavity is filled (6-inch water level). No debris would be transported to the inactive incore tunnel/reactor cavity, or outside the crane wall until after recirculation has been initiated, since all points of communication with these areas are above the minimum water level.

Debris Distribution at the Beginning of Recirculation

8) It was conservatively assumed that all latent debris is in lower containment. Some of this debris could be transported to the sump strainer during fill-up, but the remainder was assumed to be uniformly distributed in the containment pool at the beginning of recirculation. This is a conservative assumption since no credit is taken for debris remaining on structures and equipment above the pool water level.

9) The unqualified coatings in upper containment were assumed to be washed down at some point during recirculation (as opposed to being washed down during pool fill-up and spread around the pool). This is a conservative assumption since the two drain lines discharge next to the sump screens.

10) It was assumed that the unqualified coatings in lower containment would enter the recirculation pool in the vicinity of the location where they were applied. This is a reasonable assumption since unqualified coatings outside the ZOI would break down gradually, and would likely fail after recirculation has been initiated.

11) It was assumed that the debris washed down by the ice melt flow would enter the pool below the ice melt drain lines during recirculation (as opposed to the debris entering the pool before recirculation is initiated and subsequently migrating to other portions of the pool). This is a conservative assumption, since the local turbulence caused by the ice melt flow would increase the likelihood of transport.

12) It was assumed that small and large piece debris would be uniformly distributed between the locations where it is destroyed and the closest sump screen. This is a conservative assumption since it neglects the fact that some debris would be blown or washed to areas farther away from the sump during the blowdown and pool fill-up phases.

3.h.3. *Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.*

<u>TVA Response</u>

The Unit 1 original containment sump strainer test program is described in the response to ***Item 3.f.4***. The various debris loads used in the strainer testing established the ability of the sump strainer design to accommodate coating debris. This included coating failure modes as fines (maximum transport) and chips (maximum blockage).

Surrogate materials used to simulate coating debris in the testing were as follows:

- Silicon Carbide: This material was substituted for phenolic, alkyd and silicone coatings where the coatings were assumed to fail as particulates.
- Amerlock 400 NT: This material was substituted for phenolic, alkyd and silicone coatings where the coatings were assumed to fail as chips.
- Tin Particles: This material was substituted for inorganic zinc coatings which were assumed to fail as particulate.

3.h.4. *Provide bases for the choice of surrogates.*

TVA Response

The surrogate materials described in the response to ***Item 3.h.3.*** were selected on the following basis:

- Silicon Carbide: The actual phenolic, alkyd and silicone coatings used inside the WBN containment building are no longer available. Silicon carbide was selected as a substitute for these materials based upon sufficient similarities in material density and particle size distribution.
- Amerlock 400 NT: The actual phenolic, alkyd and silicone coatings used inside the WBN containment building are no longer available. Amerlock 400 NT was selected as a substitute for these materials based upon sufficient similarities in material density and chip size distribution.
- Tin Particles: This material was substituted for inorganic zinc particulate because zinc is considered to be a hazardous material. Tin was substituted for zinc based on similarities in material density and particle size distribution.

3.h.5. *Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.*

TVA Response

The type, quantity, and size distribution of coating debris generated following a postulated high energy line break at WBN was established based on the following methods/assumptions:

1) A containment walkdown was performed to identify and locate coatings in lower containment for Unit 1. Due to similarities in containment design and construction, this information also applies to Unit 2.
2) Pipe break locations were selected based on the accident scenarios that could lead to containment sump recirculation operation.
3) An affected coating ZOI was established from an assumed equivalent spherical ZOI radii to pipe break r/D of 10.0.
4) The quantity of coating debris generated was determined based on: (1) coatings (qualified or unqualified) in the pipe break ZOI will fail; (2) qualified coatings outside of the ZOI will remain intact; and (3) unqualified coatings outside of the ZOI will fail.

5) Coatings within the ZOI were assumed to fail as 10 micron particulate. Unqualified coatings (alkyd, inorganic zinc, and modified silicone paint) outside the ZOI in lower containment or subject to spray in the upper containment were also assumed to fail as 10 micron particulate.

The methods/assumptions included in the WBN coating debris generation analysis are consistent with NEI-04-07 and the associated NRC SER.

3.h.6. *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*

TVA Response

A detailed description of the failed coating characteristics is contained in the response to ***Item 3.c.1***. The assumed characteristics of the failed coating debris for WBN are consistent with NEI-04-07 and the associated NRC SER (as well as applicable test data).

3.h.7. *Describe any ongoing containment coating condition assessment program.*

TVA Response

The current Unit 1 TVA protective coating program contains requirements for conducting periodic visual examinations of Coating Service Level I and Level II protective coatings. The Unit 2 program will be the same. The inspections for Unit 2 will be performed as part of the plant preventative maintenance program to periodically evaluate the condition of the applied coatings and determine their capability for performing their intended function. These inspections will be performed by qualified personnel according to established inspection plans and acceptance criteria. Any coating defects identified as part of the periodic inspection will be identified and placed in the plant corrective action program for evaluation and disposition.

Additionally, a separate general inspection of all Coating Service Level I coating is performed during each refueling outage. Any coating defects identified as part of the outage inspection are identified and placed in the plant corrective action program for evaluation and disposition.

3.i. Debris Source Term

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.

Provide the information requested in GL 04-02 Requested Information Item 2.(f) regarding programmatic controls taken to limit debris sources in containment.

GL 2004-02 Requested Information Item 2(f)

A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced info containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, 'Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment,' to the extent that their responses address these specific foreign material control issues.

In responding to GL 2004 Requested Information Item 2(f), provide the following:

- *A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI / low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.*
- *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.*
- *A description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements.*
- *A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.*

If any of the following suggested design and operational refinements given in the guidance report (guidance report, Section 5) and SE (SE, Section 5.1) were used, summarize the application of the refinements.

- *Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers.*
- *Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers.*
- *Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers.*
- *Actions taken to modify or improve the containment coatings program*

TVA Response

Design and administrative controls are in place at WBN to ensure that potential quantities of post-accident debris are maintained within the bounds of the analyses and design bases that support ECCS and CSS recirculation functions. These same controls will be applied to Unit 2 once completed.

Following is a summary of the procedures and engineering specifications which constitute the present containment material control and inspection requirements at WBN that pertain to ensuring operability of the containment sump:

1) Surveillance Instruction 1-SI-304-2, "18 Month ECCS Containment Sump Inspection," verifies the integrity and cleanliness of the ECCS containment sump, containment spray piping, RHR suction piping, and floor drains in Accumulator Rooms 3 and 4.
2) Technical Instruction TI-61.003, "Ice Condenser Loose Debris Log," describes the steps to record, track, and evaluate any debris in the ice condenser.
3) Standard Programs and Processes (SPP) SPP-10.7, "Housekeeping/Temporary Equipment Control," delineates controls for housekeeping, material condition, and temporary equipment at TVA nuclear sites. This encompasses housekeeping responsibilities for all workers to preserve the quality of the work environment and the material condition of the plant.
4) SPP-6.0, "Maintenance and Modifications," ensures that conduct of maintenance activities and the physical implementation of design changes support safe operation of the station.
5) SPP-9.3, "Plant Modifications and Change Control," establishes a uniform process of administrative controls and regulatory/quality requirements for plant modifications and changes to engineering documents. It includes consideration of materials introduced into the containment that could contribute to sump strainer blockage.
6) SPP-9.5, "Temporary Alterations," provides the requirements for controlling temporary alterations to systems, structures and components (SSCs) of TVA's 10 CFR 50 and 10 CFR 72 facilities in a manner which ensures operator awareness, conformance with design basis and operability requirements, and preservation of plan safety and reliability.
7) Technical Instruction TI-12.07, "Containment Access," provides documentation of containment entry/exit and cleanliness (housekeeping) requirement when the plant is in Modes 1 through 4. Performance ensures no loose debris (rags, trash, clothing, failed protective coatings, tools, etc.) is present in containment, specifically debris that could impact RHR, CSS, and ECCS operability due to adverse impact on the containment sump.
8) SPP-6.5, "Foreign Material Control," provides the requirements for maintaining cleanliness by preventing the uncontrolled introduction of foreign material such as maintenance residue, dirt, debris, or tools into open systems or components, and recovery from intrusion of foreign material.

9) General Engineering Specification G-55, "Technical and Programmatic Requirement for Protective Coating Program at TVA Nuclear Plant," provides the technical and programmatic requirements for the protective coating programs at TVA nuclear plants.

10) Modification/Addition Instruction MAI-5.3, "Protective Coatings," covers the technical and verification requirements to implement a protective coating program at WBN that meets TVA's commitments as defined in Engineering Specification G-55.

11) Technical Instruction TI-279, "Modification Review for Sources and Quantities of Aluminum and Zinc," provides the requirements for controlling design changes and modifications to ensure the inventory of light metals (aluminum and zinc) inside containment is maintained within FSAR limits and design bases. This procedure has been revised to include Unit 2.

Collectively, these documents provide the technical and programmatic controls necessary to ensure that design change, maintenance, and modification activities are conducted in a manner that assures operability of the containment sump. These procedures will be updated as required to include Unit 2 as part of the process for developing Unit 2 operating procedures.

3.j. Screen Modification Package

The objective of the screen modification package section is to provide a basic description of the sump screen modification.

3.j.1. *Provide a description of the major features of the sump screen design modification.*

TVA Response

The WBN advanced design containment sump strainers are based on a "stacked disk" strainer design manufactured by Performance Contracting, Incorporated (PCI). The "stacked disk" design is comprised of a series of approximately 1" thick disks covered with a stainless steel skin which is punched with 0.085" diameter flow openings. After passing through the strainer skin, intake flow is directed to a central flow channel. The strainer disks are stacked on top of each other to form the strainer modules. See photo below.

WBN has one recirculation strainer assembly that feeds a common suction sump via a plenum. The single strainer assembly consists of 23 vertically oriented strainer stacks, 14 of which are taller Type "A" strainers and 9 of which are shorter Type "B" strainers. Each of the Type "A" strainers consists of 4 strainer modules that are vertically stacked on top of each other. The first module has 7 disks and the other three modules have 6 disks. Each of the Type "B" strainers consists of 3 strainer modules that are vertically stacked on top of each other with each having 7 disks. The 23 strainers provide a total of 4,675.1 ft^2 of area. Flow leaves each of the strainers where it enters a rectangular, horizontally oriented collection plenum that is positioned over the top of the sump pit.

3.j.2. *Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications.*

TVA Response

The only modifications required to support installation of the advance design sump strainers were demolition of the original flat plate sump intake screen and the minor rerouting of electrical conduit to establish the required clearances.

3.k. **Sump Structural Analysis**

The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces.

Provide the information requested in GL 2004-02 Requested Information Item 2(d)(vii).

GL 2004-02 Requested Information Item 2(d) (vii)

Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post LOCH blockage under flow conditions.

3.k.1. *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*

TVA Response

The structural evaluations of the WBN sump strainers and flow plenum assembly were performed using a combination of manual calculations and finite element analyses using the GTSTRUDL Computer Program and the ANSYS Computer Program. The evaluations follow requirements imposed by the TVA Design Specification for the containment building sump strainers which are consistent with the plant design and licensing basis requirements. A summary of the design inputs, design codes, loads and load combinations used in the strainer/plenum structural analyses follows:

Design Input

The design inputs used in the structural analysis of the WBN sump strainers and plenum assembly consisted of the following.

1) Strainer/plenum arrangement and dimensional data from the appropriate component design and fabrication drawings.
2) Strainer/plenum material types from the appropriate component design and fabrication drawings.
3) Design and maximum operating temperatures from the strainer/plenum design specification.
4) WBN plant specific seismic acceleration response spectra from the strainer/plenum design specification.
5) Structural analysis load type, combinations and acceptance criteria from the strainer/plenum design specification.

Design Codes

The WBN containment sump strainers and flow plenum assembly were designed, fabricated and inspected in accordance with the following codes and standards (unless otherwise stated, the standards were the latest in effect on the date of the purchase order):

1) American Institute of Steel Construction (AISC), Speciation for the Design, Fabrication, and Erection of Structural Steel for Buildings, 7th Edition, adopted February 12, 1969.
2) ASME Section II, "Material Specifications."
3) ASME Section III, Division 1, Subsection NF, "Supports," 2004 Edition thru July 2005 Addenda.
4) ASME Section V, "Non-Destructive Examination," 2004 Edition thru July 2005 Addenda.
5) ASME Section IX, "Welding and Brazing Qualification," 2004 Edition thru July 2005 Addenda.
6) AWS D1.6 – 1999, "Structural Welding Code – Stainless Steel."

The primary design and fabrication standard for the WBN strainer equipment was the AISC standard cited above. The equipment structural analysis acceptance criteria were primarily established in accordance with this standard. In circumstances where the AISC Code does not provide adequate guidance for a particular component, other codes or standards are used for guidance. These alternate codes are discussed briefly below.

The AISC Code does not provide any design guidelines for perforated plate. Therefore, the equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1989 Edition, were used to calculate the perforated plate stresses. The acceptance criteria are also based on this code. In addition, the AISC Code does not specifically cover stainless steel materials. Since the strainers are fabricated entirely from stainless steel, the ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities," was used to supplement the AISC in any areas related specifically to the structural qualification of stainless steel. Only the basic acceptance criteria (allowable stresses) are used from the ASME Code and load combinations and allowable stress factors for higher service level loads are not used.

The strainer also has several components made from thin gage sheet steel and cold formed stainless sheet steel. For these components, SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," was used where rules specific to thin gage and cold form stainless steel are applicable. The rules for Allowable Stress Design (ASD) as specified in Appendix D of this code were used. This is further supplemented by the AISC Code where the ASCE Code is lacking specific guidance. Finally, guidance is also taken from AWS D1.6, "Structural Welding Code Stainless Steel," as it relates to the qualification of stainless steel welds.

Structural Analysis Loads, Load Combinations and Acceptance Criteria

The structural analysis of the strainers and associated flow plenum considered the following design basis loads.

1) DW: Strainer and support dead weight loads and forces
2) TOL: Thermal effect loads during normal operation (loads imposed by a conservatively assumed maximum normal operating temperature of 140°F)
3) OBE: Seismic loads generated by the operating basis earthquake
4) SSE: Seismic loads generated by the safe shutdown earthquake
5) TAL: Thermal effect loads during accident operation (loads imposed by the maximum accident operating temperature of 190°F)
6) JIL: Jet impingement equivalent static load (if applicable) – Note 3
7) DIL: Debris impact equivalent static load
8) DP: Differential pressure across perforated plates and other pressure boundaries – Note 4
9) DEB: Debris Weight – Note 5

These design basis loads were combined and confirmed to meet the indicated acceptance criteria as follow:

Load Combination 1:	DW + DP + DEB ≤ S	Note 1
Load Combination 2:	DW + OBE ≤ S	Note 1
Load Combination 3:	DW + TOL + OBE ≤ 1.5 x S	Note 1
Load Combination 4:	DW + TOL + SSE ≤ 1.6 x S	Note 1
Load Combination 5:	DW + DP + DEB + TAL ≤ 1.6 x S	Note 1
Load Combination 6:	DW + JIL + DIL + SSE ≤ 1.6 x S	Note 2

Notes

1) For structural steel, the "S" value is the required section strength based on the elastic design methods and the allowable stresses defined in Part 1 of the AISC specification, Seventh Edition. The 33% increase in allowable stresses for steel due to seismic or wind loadings permitted by the AISC standard was not applied to this evaluation. When alternate standards were used to supplement the AISC specification as indicated below, the "S" value was consistent with the AISC definition except that the allowable stresses were taken from the alternate standard.

   For perforated plates, the "S" value was the allowable stress from the ASME Section III Boiler and Pressure Vessel Code, Section III, 1989 Edition including Appendix A, Article A-8000 provisions for calculating perforated plate stresses.

   For concrete anchor bolts, the tensile and shear forces shall not exceed the allowable loads for the selected anchor bolts in TVA Design Standard No. DS-C1.7.1, Revision 11. TVA concurrence with anchor bolt selection is required. Thermal stresses on anchor bolts shall be considered and minimized by the design.

2) The AISC allowable load combination for Load Case 6 shall not exceed the following limits:

$0.9 \times F_y$	for Tension or Bending Stress
$(0.9 \times F_y) \div (3.0)^{0.5}$	for Shear Stress
$0.9 \times F_{critical\ buckling}$	for Compression Stress

   Where

   Fy = minimum specified yield strength of the material, and

   $F_{critical\ buckling}$ = the compressive stress calculated by the AISC equations without the appropriate factor of safety

3) The jet impingement load (JIL) and debris impact load (DIL) are negligible for the final strainer design.

4) The differential pressure (DP) shall be the component design basis 3.5 feet of water.

5) Debris weight shall be considered for Loading Combinations 1 and 5. The debris weight on the strainer structure shall be the larger of 25 pounds per square foot applied to the total strainer/flow plenum horizontal footprint area or the maximum calculated debris weight transported to the strainer under design basis operating conditions.

6) It is not necessary to consider hydrostatic or hydrodynamic loads for the load combinations which include OBE and SSE loads.

7) Since stainless steel does not display a single, well defined modulus of elasticity, the allowable compression stress equations from the AISC specification, Seventh Edition shall not be applied to stainless steel materials. For stainless steel materials, the allowable compression stress will be based on the lower allowable from ANSI/AISC N690-1994. The allowable stresses for tension, shear, bending and bearing for stainless steel materials shall be taken from the allowables provided for carbon steel in the AISC specification, Seventh Edition.

3.k.2. *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*

TVA Response

The structural analysis of the strainer and flow plenum assemblies established that they meet the structural acceptance criteria for all applicable loadings. A summary of the limiting stress interaction ratios (i.e., calculated stress divided by allowable stress) follows:

Containment Sump Strainer and Flow Plenum Structural Analysis Interaction Ratios

Strainer Component	Maximum Stress Ratio	Flow Plenum Component	Maximum Stress Ratio
Radial Stiffener (w/ Collar)	0.86	Support Beams	0.09
Tension Rods	0.46	Support Floor Beam Local Web	0.95
Edge Channels	0.78	Top Cover Plate	0.84
Cross Bracing	0.41	Lower Deck Plate	0.25
Hex Coupling	0.31	Plate Beam Over Pit	0.24
Core Tube	0.18	Hex Couplings	0.22
Radial Stiffeners (Bent Portion)	0.28	Plenum Box Channels	0.17

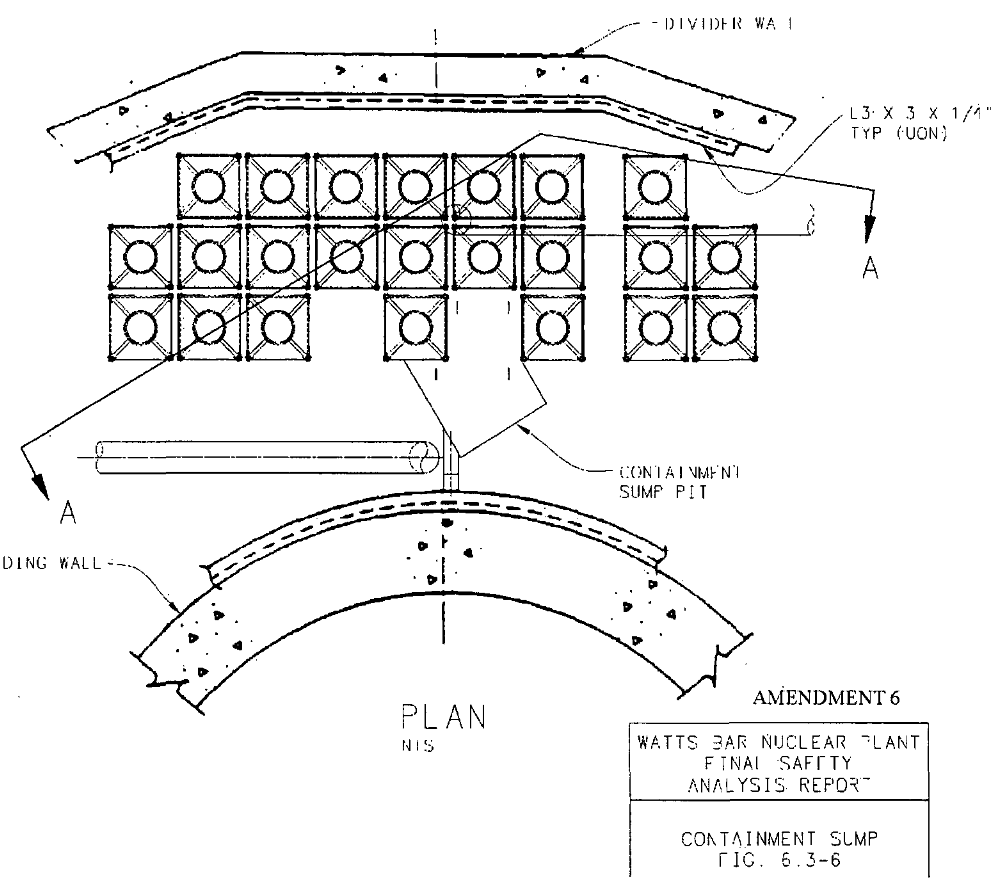
Containment Sump Strainer and Flow Plenum Structural Analysis Interaction Ratios

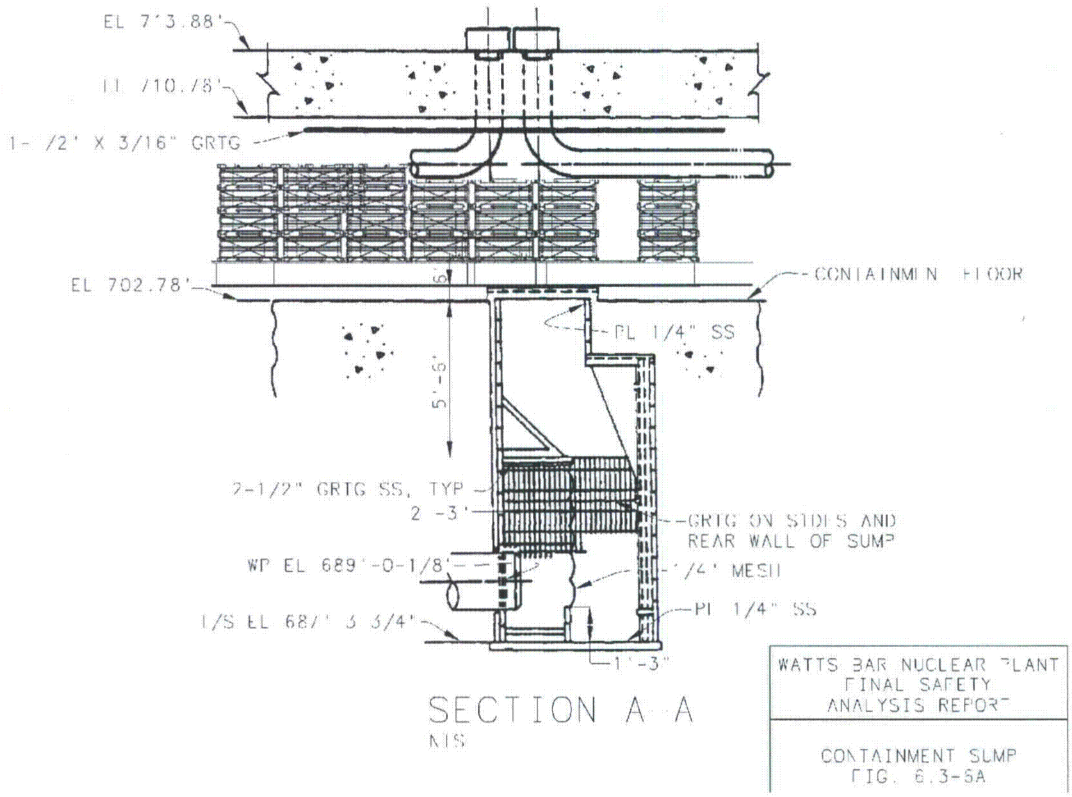
Strainer Component	Maximum Stress Ratio	Flow Plenum Component	Maximum Stress Ratio
Spacer	0.86	Plenum Box Channel Local Web	0.18
Spacer Separation	0.93	Lower Deck Drainage Perforated Plate	0.48
Perforated Plate (DP Case)	0.22	Lower Deck Drainage Plate Openings	0.03
Perforated Plate (Seismic Case)	0.04	Top Strip to Hex Couple Bolts	0.47
Perforated Plate (Inner Gap)	0.13	Channel to Support Beam Bolts	0.34
Inner Gap Buckling	0.20	Channel Local Flange at Bolts	0.95
Wire Stiffener	0.54	Bottom Plates to Beam Bolts	0.20
Perforated Plate (Core Tube End Cover DP Case)	0.29	Channel Splice Plate Bolts	0.37
Radial Stiffening Spokes of the End Cover Stiffener	0.41	Channel to Channel Splice Welds	0.90
End Cover Sleeve	0.14	Channel Splice Plate	0.65
Weld of End Cover Stiffener to End Cover Sleeve	0.12	Channel to Channel Welds at Curb Corner	0.37
Weld of Radial Stiffener to Core Tube	0.09	Concrete Expansion Anchors	0.70
Edge Channel Rivets	0.08	Floor Beam Local Flange at Bolts	0.80
Inner Gap Hoop Rivets	0.04	Clip Angle to Sump Curb Weld	0.66
End Cover Rivets	0.00	TS to Strip Plate	0.27
Connecting Bolts	0.31	Strip Plate Local Stress at TS connection	0.33

3.k.3. *Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).*

<u>TVA Response</u>

The location of the WBN containment sump strainers was reviewed relative to the existing containment pipe break dynamic effects analysis. The strainers are located in a relatively protected location in the lower containment below the refueling cavity as shown in Unit 1 UFSAR Figures 6.3-6 and 6.3-6a (Figures are provided herein for convenience.). The review found that the location of the strainers was not subject to jet impingement, pipe whip or missile impacts from high energy line breaks inside containment. This evaluation is consistent with current WBN licensing basis which has deleted the dynamic effects of a primary system pipe break from consideration based on the application of leak-before-break criteria. As such, jet impingement, pipe whip and debris impact loads were not included in the strainer/plenum assembly structural analysis.





3.k.4. *If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.*

TVA Response

The WBN containment sump strainer design does not credit back flushing. The strainer structural analysis did not consider reverse flow accordingly.

3.I. Upstream Effects

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

Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 Requested Information Item 2(d)(iv).

GL 2004-02 Requested Information Item 2(d) CM

The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

3.I.1. *Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.*

3.I.2. *Summarize measures taken to mitigate potential choke points.*

3.I.3. *Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.*

3.I.4. *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

TVA Response (items 3.I.1. through 3.I.4.)

Containment walkdowns for Unit 1 were performed in accordance with the guidance in NEI 02-01; Unit 2 is similar due to design and construction. These walkdowns showed that there are three potential chokepoints that could prevent adequate water inventory from reaching the containment sump: the two refueling canal drains and the drains in Accumulator Rooms 3 and 4.

The drains in the Accumulator Rooms allow the small amount of spray flow that directly hits the air return fans to be returned inside the polar crane wall. Curbs are present in the upper compartment around the fan suction that prevents spray water on the refueling floor from spilling through the fans. Thus, the only potential debris from the spray system entering the Accumulator Rooms is very small debris that has traveled through the strainers. Neither the upper compartment nor the Accumulator Rooms are subjected to high energy jets. The only potential for debris in these compartments is failed coatings. The size of the failed coatings or debris that passes through the spray pumps is small and will not block any of these drains. RMI debris (large or small) will not be present to block these drains. It is therefore concluded that there will be no water inventory holdup or diversion due to debris blockage at chokepoints.

The 14" drains in the refueling canal discharge on opposite sides of the sump strainer area. The plant was designed such that almost all of the spray water flows to lower containment through these two drain lines. If these drain lines were to become clogged with debris, it could eventually starve the sump. However, given the size of these lines and the debris that would be washed down with the sprays (latent debris, paint chips, and possibly a small amount of LOCA generated fines blown past the ice baskets), these lines are not likely to become clogged.

The debris transport analysis also identified one additional "set" of potential chokepoints which could prevent adequate water inventory from reaching the containment sump. That "set" of chokepoints is the 20 ice condenser drains that drain ice melt water from the ice condenser to the lower compartment. If one of the 20 ice condenser drain lines were to become clogged, the water would flow to one of the other drains. It is not likely that all 20 drains would become clogged. If all drains were to clog, the ice melt water would spill over through the ice condenser bay doors (this is the normal path early in the event when the ice melt overwhelms the drain lines). Therefore this chokepoint is not considered a problem.

An inspection for non-LOCA generated material that could potentially obstruct recirculating water is conducted as part of WBN's containment cleanliness inspection program prior to restart following a refueling outage. This program specifically addresses the need to ensure that the containment is free of items that could be washed to the sump.

3.m. **Downstream effects – Components and Systems**

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams. Provide the information requested in GL 04-02 Requested Information Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and dose tolerance locations in the ECCS and CSS downstream of the sump.

GL 2004-02 Requested Information Item 2(d)(v)

The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

GL 2004-02 Requested Information Item 2(d)(vi)

Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

3.m.1. *If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE), briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas.*

3.m.2. *Provide a summary and conclusions of downstream evaluations.*

3.m.3. *Provide a summary of design or operational changes made as a result of downstream evaluations.*

TVA Response (items 3.m.1. through 3.m.3.)

The evaluations listed below were developed to address effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams for Unit 1. The evaluation included source terms for Min-k and 3M fire-wrap which are not used in Unit 2. Therefore, the evaluations are applicable but bounding for Unit 2. Close-tolerance subcomponents in pumps, valves, and other ECCS and CSS components were evaluated for potential plugging or excessive wear due to extended post-accident operation with debris laden fluids. The evaluations were developed in accordance with WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," prior to issuance of Revision 1 and its accompanying NRC SER. No exceptions were taken to the WCAP-16406-P methodology.

A revision to the evaluation was issued to incorporate the methodology from WCAP-16406-P, Revision 1. The results of the revised evaluation indicate that the WBN ECCS equipment will adequately perform during the required mission time as detailed in the Tables below.

Calculation Note, "Watts Bar Unit 2 GSI Down Stream Effects Debris Ingestion Evaluation"

The quantity of debris in the recirculating fluid that passes through the sump is characterized in terms of volume concentration. For downstream effects, this debris concentration (γ) is defined as the ratio of the solid volume of the debris in the pumped fluid to the total volume of water that is being recirculated by the ECCS and CSS.

$$\gamma = 0.0002262$$

The mass of debris in the recirculating fluid that passes through the sump is characterized in terms of parts per million (ppm). For downstream effects, the total initial debris concentration comprised of the individual debris concentrations is defined as the ratio of the solid mass of the debris in the pumped fluid to the total mass of water that is being recirculated by the ECCS and CSS.

Debris Type	Concentration
Fibrous	1 ppm
Particulate	241 ppm
Coatings	593 ppm
Total	835 ppm

Calculation Note, "Watts Bar Unit 2 Sump Debris Downstream Effects Evaluation for ECCS Equipment"

This evaluation was issued to incorporate the methodology from WCAP-16406-P, Revision 1. The results of the revised evaluation indicate that the WBN ECCS equipment will perform adequately during the required mission time. This addresses Unit 1 ***Open Item 8***.

The effects of debris ingested through the containment sump screen during the recirculation mode of the ECCS and CSS include erosive wear, abrasion and potential blockage of flow paths. The smallest clearance found for the WBN heat exchangers, orifices, and spray nozzles in the recirculation flow path is 0.375 inches for the containment and RHR spray nozzles; therefore, no blockage of the ECCS flow paths is expected with the WBN Bar Unit 2 sump screen hole size of 0.085 inches.

Instrumentation Blockage Evaluation:

The instrumentation tubing is also evaluated for potential blockage of the sensing lines. The transverse velocity past this tubing is determined to be sufficient to prevent debris settlement into these lines, so no blockage will occur. The transverse velocity past this tubing is documented in Table 1. The reactor vessel level instrumentation system (RVLIS) is also evaluated. The WBN RVLIS is a Westinghouse design and, based on this evaluation, no effect on its performance is expected from the debris.

Table 1: Instrumentation Evaluation

Location	Instrumentation No.	Transverse Velocity (ft/s)	Failure (yes/no)
Charging/SI Flow	FT-63-170	12.43	no
	FE-63-27, 29, 31, 33	14.92	no
High Head SI Flow	FE-63-20, 151	20.12	no
	FE-63-159, 160, 161, 162	22.08	no
	FE-63-122, 123, 124, 125	19.89	no
RHR/Low Head SI Flow	FE-63-91, 92	5.99	no

Heat Exchanger Evaluation:

The WBN heat exchangers, orifices, and spray nozzles were evaluated for the effects of erosive wear for a constant debris concentration of 835 ppm over a mission time of 30 days. The erosive wear on these components is determined to be insufficient to affect the system performance. The heat exchanger wear and plugging evaluation results are documented in Tables 2 and 3, respectively.

Table 2: Heat Exchanger Wear Evaluation

	D_o (in)	Internal t_m (in)	External t_m (in)	t_{actual} (in)	t_{eroded}	Failure (yes/no)
RHR Heat Exchangers	0.625	0.0114	0.0144	0.049	2.28E-4	no
Seal Water Heat Exchanger	0.750	0.0046	0.0173	0.049	2.28E-4	no
CSS Heat Exchangers	0.750	0.0069	0.0173	0.049	2.28E-4	no

Table 3: Heat Exchanger Plugging Evaluation

	Number	Tube ID (in)	Plugging (yes/no)
RHR Heat Exchangers	2	0.527	no
Seal Water Heat Exchanger	1	0.652	no
CSS Heat Exchangers	2	0.652	no

Orifice Evaluation:

If the orifice inside diameter due to erosive wear is changed by less than 3%, the input on system performance may be considered negligible. This criterion was established in WCAP-16406-P which states that an insignificant amount of wear occurs when the system flow through the orifice is changed by less than 3%. This evaluation considers the initial ratio of the diameters before erosive wear and the ratio of the diameters after erosive wear for single plate and multiple plate multiple hole orifices.

Flow restricting, wear, and plugging evaluations for the single plate, multiple plate, and barrel orifices can be found in Tables 4 through 9.

Table 4: Single Plate Flow Restricting Orifice Wear Evaluation

Orifice Location	Number	B_0	B_1	$\Delta Q/Q$	Failure (yes/no)
Charging Pump Header	1	0.79581	0.79583	0.00010	no

Table 5: Multiple Plate Orifice Wear Evaluation

At time 0 hours	$\sum a_i$ (in^2)	Pipe Area (in^2)	f_0
Plate 1	12.370	36.456	0.339
Plate 2	11.486	36.456	0.315
Plate 3	13.253	36.456	0.364
At mission time (720 hours)			f_1
Plate 1	12.473	36.465	0.342
Plate 2	11.598	36.465	0.318
Plate 3	13.350	36.465	0.366

Table 6: Multiple Plate Orifice Wear Evaluation

Orifice Location	Number	R_{0i}	R_{1i}	$\Delta Q/Q$	Failure (yes/no)
RHR cold leg injection flow (1)	2	16.246	15.914	0.0104	no
RHR cold leg injection flow (2)	2	19.516	19.061	0.0118	no
RHR cold leg injection flow (3)	2	13.655	13.408	0.0092	no

Table 7: Barrel Orifice Wear Evaluation

Location	ID No.	Bore Size (in)	Orifice Velocity (ft/s)	Reynolds Number	Friction Factor
CC pump mini-flow line	OR-62-106, 110	2.624	3.56	6.03E04	0.030

Table 8: Barrel Orifice Wear Evaluation

Location	ID No.	L (in)	fL/d_0	fL/d_1	ΔQ/Q	Failure (yes/no)
CC pump mini-flow line	OR-62-106, 110	13	0.1486	0.1468	0.000	no

Table 9: Orifice Plugging Evaluation

Orifice Location	Number	Bore Size (in)	Plugging (yes/no)
Charging pump header	1	2.736	no

Spray Wear and Plugging Evaluation:

The WCAP established a 10% limit on increased flow as a result of spray nozzle erosion. The results of the analyses summarized in Tables 10 and 11 show that the CSS and RHR spray nozzle increase is less than 2.5% and thus is acceptable.

Table 10: Spray Nozzle Wear Evaluation

	Nozzle Velocity (ft/sec)	Erosive Wear (in)	D_1 (in)	Flow Increase (%)
CSS Spray Headers	44.18	1.9E-3	0.3789	2.09
RHR Spray Headers Unit 2	41.25	1.6E-3	0.3782	1.71

Table 11: Spray Nozzle Plugging Evaluation

	Number per Header	Orifice Size (in)	Plugging (yes/no)
CSS Spray Headers	263	0.375	no
RHR Spray Headers Unit 2	140	0.375	no

Pump Wear Evaluation:

For pumps, the effects of debris ingestion through the sump screen on three aspects of operability, including hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration) of the pump, were evaluated and are recorded in Table 12. The hydraulic and mechanical performances of the pump were determined to not be affected by the recirculating sump debris.

Unit 2 has Engineered Safety Feature (ESF) atmospheric filtration systems, the Auxiliary Building Gas Treatment System, and the Emergency Gas Treatment System. Evaluation of a primary seal passive failure is not required by NUREG-0800, and so the backup seal is not necessary to limit the leakage. Infrequent minor ECCS pump seal leakage that may occur during normal operation is bounded by the existing offsite dose analysis. The total ECCS recirculation loop leakage evaluated in the offsite dose analysis is 3,760 cc/hr. Since no primary seal failure is imposed by the LOCA dose analysis and primary seal failure is unlikely under these conditions, no adverse effect on the backup bushing is expected.

The change in the pump wear ring gap due to abrasive wear was calculated and the resulting reduction in the pump discharge flow evaluated. For all of the Table 12 pumps, the hydraulic flow margin is assumed to be positive at the start of containment recirculation.

Because the increased clearance for the pumps is within the 3X design clearance, no effect on the hydraulic performance of the Table 12 pumps is expected.

Table 12: Hydraulic Performance Evaluation

Pump	Normal Wear (mils)	Erosive Wear (mils)	Abrasive Wear (mils)	Total Wear (mils)	Increased Clearance (mils)	3X Design Clearance (mils)
RHR	3.0	3.97E-3	1.98	1.99	27.98	69
CS	0.0	3.97E-3	1.67	1.68	28.67	81
SI	0.0	3.97E-3	0.30	0.30	10.30	30
CC	3.0	3.97E-3	0.30	0.30	13.30	30

<u>Calculation Note, "Watts Bar Unit 2 Sump Debris Downstream Effects Evaluation for ECCS Valves"</u>

The Centrifugal Charging Pump cold leg injection, Safety Injection cold leg injection and Safety Injection hot leg injection throttle valves are being replaced with Copes Vulcan (SPX Corporation) class 1513 globe valves. This change eliminated the need for barrel orifices in the injection lines. According to the criteria established in WCAP-16406-P, all ECCS valves pass their respective evaluations. A more detailed summary for these remaining valves can be found below.

Valve Plugging Evaluation:

Twelve valves meet the criteria for specific plugging evaluation. Because the valves are currently being positioned to ensure that no plugging will result, all of the valves pass the evaluation. The results are summarized in Table 13.

Table 13: Valve Plugging Evaluation

#	System	Customer ID	Type	Size (in)	Minimum Clearance (in)	Evaluation Results
9	SI	63-542	globe	2	0.0925	No blockage
10	SI	63-544	globe	2	0.0925	No blockage
11	SI	63-546	globe	2	0.0925	No blockage
12	SI	63-548	globe	2	0.0925	No blockage
24	SI	63-550	globe	2	0.0925	No blockage
25	SI	63-552	globe	2	0.0925	No blockage
26	SI	63-554	globe	2	0.0925	No blockage
27	SI	63-556	globe	2	0.0925	No blockage
76	CVCS	63-582	globe	1.5	0.1257	No blockage
77	CVCS	63-583	globe	1.5	0.1257	No blockage
78	CVCS	63-584	globe	1.5	0.1257	No blockage
79	CVCS	63-585	globe	1.5	0.1257	No blockage

Sedimentation:

Twenty-three valves meet the requirements for a specific sedimentation evaluation. All the valves passed the evaluation; the results are summarized in Table 14.

Table 14: Sedimentation Evaluation

#	System	Customer ID	Type	Size (in)	Minimum Flow Rate (gpm)	Velocity (ft/s)	Acceptable? ($v \geq 0.42$ ft/s)
21	SI	FCV-63-22	gate	4	628	16.16	yes
22	SI	FCV-63-152	gate	4	636	16.37	yes
23	SI	FCV-63-153	gate	4	636	16.37	yes
28	SI	63-551	piston check	2	154	15.85	yes
29	SI	63-553	piston check	2	154	15.85	yes
30	SI	63-555	piston check	2	154	15.85	yes
31	SI	63-557	piston check	2	154	15.85	yes
32	SI	63-560	swing check	10	154	0.63	yes
33	SI	63-561	swing check	10	154	0.63	yes
34	SI	63-562	swing check	10	154	0.63	yes
35	SI	63-563	swing check	10	154	0.63	yes
51	RHR	FCV-74-33	gate	8	1,785	11.48	yes
52	RHR	FCV-74-35	gate	8	1,785	11.48	yes
56	RHR	63-633	swing check	6	1,000	11.44	yes

Table 14: Sedimentation Evaluation

#	System	Customer ID	Type	Size (in)	Minimum Flow Rate (gpm)	Velocity (ft/s)	Acceptable? ($v \geq 0.42$ ft/s)
57	RHR	63-632	swing check	6	1,000	11.44	yes
58	RHR	63-634	swing check	6	1,000	11.44	yes
59	RHR	63-635	swing check	6	1,000	11.44	yes
60	RHR	FCV-63-93	gate	8	2,096	13.49	yes
61	RHR	FCV-63-94	gate	8	2,096	13.49	yes
86	RSPRAY	FCV-72-40	gate	8	1,556	10.01	yes
87	RSPRAY	FCV-72-41	gate	8	1,556	10.01	yes
88	RSPRAY	72-562	check	8	1,556	10.01	yes
89	RSPRAY	72-563	check	8	1,556	10.01	yes

Wear:

Twelve valves met the criteria for a detailed wear evaluation. No valves passed the evaluation using a constant debris wear model; thus, a depleting debris wear evaluation was performed. The results are summarized in Table 15.

Table 15 – Constant Debris Wear Analysis

Customer ID	System	$\Delta A/A_o$	Acceptable?
63-542	SI	132.79%	no
63-544	SI	37.50%	no
63-546	SI	37.50%	no
63-548	SI	132.79%	no
63-550	SI	34.66%	no
63-552	SI	34.66%	no
63-554	SI	34.66%	no
63-556	SI	34.66%	no
63-582	CVCS	5.38%	no
62-583	CVCS	5.38%	no
63-584	CVCS	5.38%	no
63-585	CVCS	5.38%	no

Using the depleting debris wear model detailed in WCAP-16406-P, all valves passed the evaluation. The results are summarized in Table 16.

Table 16 – Depleting Debris Wear Evaluation

Customer ID	System	$\Delta A/A_o$	Acceptable?
63-542	SI	1.71%	yes
63-544	SI	0.49%	yes
63-546	SI	0.49%	yes
63-548	SI	1.71%	yes
63-550	SI	0.46%	yes
63-552	SI	0.46%	yes
63-554	SI	0.46%	yes
63-556	SI	0.46%	yes
63-582	CVCS	0.07%	yes
63-583	CVCS	0.07%	yes
63-584	CVCS	0.07%	yes
63-585	CVCS	0.07%	yes

3.n. Downstream Effects – Fuel and Vessel

The objective of the downstream effects, fuel and vessel section is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

3.n.1. *Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793), as modified by NRC staff comments on that document. Briefly summarize the application of the methods. Indicate where the WCAP methods were not used or exceptions were taken, and summarize the evaluation of those areas.*

TVA Response:

The following evaluations consider the effects of debris carried downstream of the containment sump screen and into the reactor vessel on core cooling, including fuel and vessel blockage. These evaluations were performed in accordance with WCAP-16406-P, "Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculation Fluid," with no exceptions taken.

Calculation Note, "Watts Bar GSI-191 Downstream Effects – Vessel Blockage Evaluation"

In this evaluation, it was found that all evaluated dimensions of essential flow paths through the reactor internals are adequate to preclude plugging by sump debris. There is sufficient clearance for debris that may pass the containment sump screen since the limiting dimensions of the essential flow paths in the upper and lower internals are all greater than the maximum debris dimension. The maximum debris dimension is defined as 2 times the sump screen hole diameters.

The smallest clearance found was 1.85 inches; therefore, any screen with holes smaller than 0.92 inches will not cause plugging by debris in the vessel. The WBN replacement sump screen has holes with a diameter of 0.085 inches.

Calculation Note, "Watts Bar GSI-191 Downstream Effects Debris Fuel Evaluation"

Further support of this statement is provided by the results of the WCAP-16406-P, Revision 1 evaluation performed for Unit 1 for fibers. The conclusion of this evaluation indicates that the amount of fibrous debris generated by a LBLOCA in WBN will not produce a fibrous debris build-up on the underside of the fuel bottom nozzle that exceeds the acceptance criterion of 0.027 inches. This conclusion is based on fibrous debris bypass test data specific to Unit 1 conditions which bound Unit 2. Since a continuous fiber bed thicker than 0.125 inches does not form, adequate long term core cooling will be provided to all WBN fuel assemblies. Further, WCAP-16793-NP states that the formation of a fibrous debris bed on the underside of the fuel assembly bottom nozzles will not cause sufficient blockage to prevent long-term core cooling.

<u>WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid"</u>

In WCAP-16793-NP, three supporting topical areas were evaluated to demonstrate that long-term core cooling would be maintained post-accident with the ECCS aligned to recirculate coolant from the containment sump to the core. The selection of the topical areas was based on the uncertainty perceived to be associated with each area. The evaluations presented are either extreme cases or parametric studies that demonstrate margin in the PWR design. These topical areas are:

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

The evaluations performed for the three areas identified above, in conjunction with other information, provide reasonable assurance of long-term core cooling for all plants within the scope of WCAP-16793-NP. This WCAP is applicable to and bounds Units 1 and 2. The evaluations presented were either extreme cases or parametric studies that demonstrate margin in the PWR design. These topical areas are:

1. Evaluation of fuel clad temperature response to blockage at the inlet to the core. The evaluation addressed a blockage of about 99.4% of the core inlet area, or alternatively, flow into the core was provided by the flow area of a single fuel assembly. The evaluation demonstrated that adequate core cooling flow would be established such that negligible impact on clad temperature would be expected due to blockage alone.
2. Evaluation of the impact of both the reduction of flow at a fuel grid, and the precipitation of chemical product on the surface of fuel cladding. A range of thermal conductivities for the precipitation were considered for both of these evaluations, ranging from a low value of 0.1 Btu/(hr-ft-°F) to 0.9 Btu/(hr-ft-°F). Over the range of conditions considered, the cladding surface temperature was, in all cases, evaluated to be below 800°F.
3. Evaluation of chemical effects in the core region to form precipitation on the cladding surface. Considering the variation in plant-specific chemistries, this evaluation was performed by extending the method of WCAP-16530-NP to estimate the potential for plate-out on the surface of fuel cladding.

In summary, reasonable assurance of long-term core cooling for all plants was demonstrated by the following:

1. The size of holes in replacement sump screen designs limits the size of debris that is passed through the screen during operation of the ECCS in the recirculation mode.
2. Based on available test observations, the characteristic dimension of this debris is typically less than the screen hole size, even for fibrous debris. Consequently, debris buildup at critical locations in the reactor vessel and core is not expected.

3. Based on data presented internationally during the resolution of the boiling water reactor (BWR) strainer performance concerns, fibrous debris was observed to not strongly adhere to fuel cladding. Thus, the small size of the debris and its tendency to not adhere to fuel indicates that long-term core cooling of the fuel will not be impaired by either the collection of fibrous and particulate debris in fuel elements, or by the collection of fibrous debris on fuel cladding surfaces.
4. Supporting calculations have demonstrated long-term core cooling will be maintained with about 99.4% of the core blocked. The cladding temperature response to blockage at grids and the collection of precipitation on clad surfaces were also demonstrated to be acceptable with resulting cladding temperatures less than 400°F.
5. A method to evaluate chemical effects on fuel has been developed, applied to several "worst case" plant chemistries, and acceptable clad temperatures were calculated.

It was concluded that reasonable assurance of acceptable long-term core cooling with debris and chemical products in the recirculating fluid is demonstrated for all plants. Items 1 through 4 are directly applicable to all PWRs including Units 1 and 2.

A comparison to the conditions evaluated by the sample calculation in WCAP-16793-NP was made to Units 1 and 2 plant parameters. This comparison is summarized below:

Comparison of LOCADM Sample Calculation Parameters to Unit 2 Plant Conditions

Parameter	Sample Calculation	WBN 2
Core Thermal Power Rating	3,188 MWth	3,411 MWth
Fiber (fiberglass) Debris Load	7,000 ft^3	6.25 ft^3
Calcium Silicate Debris Load	80 ft^3	0 ft^3
Sump pH Control Buffer Agent	Sodium Hydroxide	Sodium Tetraborate
Hot Leg Switchover Time	13 hours	3 hours
Aluminum Surface Area in Containment - unsubmerged	15,189 ft^2	1,146 ft^2
Aluminum Surface Area in Containment - submerged	799 ft^2	203 ft^2

Based on this comparison, it was concluded the sample calculation in WCAP-16793-NP was conservative with respect to Unit 2 plant conditions.

TVA will complete the WBN in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 following issuance of the final NRC SER for Topical Report No. WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." Based on available margins, it is anticipated that the remaining in-vessel downstream effects issues can be addressed by demonstrating that WBN plant-specific conditions are bounded by the evaluation in the final report. Following issuance of the SE, a submittal will be made documenting the final WBN in-vessel downstream effects evaluation.

Unit 2 will use the alternate p-grid design (or later design) for the robust fuel assemblies (RFA-2) fuel used in Unit 2. The original p-grid design at the bottom of the fuel had cruciforms that partially bisected the inlet flow hole in the bottom of the fuel. This was evaluated to not be a problem, but the alternate p-grid design raises the grid an additional amount away from the bottom nozzle which allows further clearance for debris passage and additional conservatism in the design.

3.o. Chemical Effects

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

3.o.1. *Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.*

Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML072600425).

TVA Response

The purpose of this analysis is to determine the type and quantity of chemical precipitates which may form post-LOCA. This input is intended to be used for screen performance testing and may be used in the evaluation of chemical effects on downstream equipment. TVA has calculated the quantities of precipitates expected to form post-LOCA using the chemical model/methodology developed in WCAP-16530-NP, prior to release of the accompanying NRC SER. Based on the relatively limited quantities of precipitate material predicted by the calculation and the large strainer surface area to debris loading ratio, the WBN replacement sump screen was tested with chemical precipitate surrogates during certification testing only in the maximum coating inventory test.

Excel Spreadsheet: "WOG Chemical Effects Calculator 19 WBN corrected 4.1 pH Cold.xls"

This calculation determines the type and expected quantity of chemical products that would be expected to form in the recirculation fluid specifically for WBN. No deviations were taken to the WCAP-16530-NP methods.

Input assumptions (and their basis) used to determine chemical effects loading:
pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects are listed in the input tabs of the spreadsheet.

The materials expected to contribute to the formation of chemical precipitates are: submerged aluminum, non-submerged aluminum, Aluminum Silicate, and concrete. The buffering agent, NaTB, is used to buffer the sump pH from a minimum pH of 4.1 to a maximum pH of 8.2 post-LOCA. A sensitivity case was performed with the recirculation water volume of 54,907 ft^3.

Table 1 shows the recirculation water volume, the inputs for the amount of materials, and the buffering agent used in the chemical effects evaluation for WBN.

Supplemental Response to Address GL 2004-02 Actions at Unit 2
Using Revised Content Guide for GL 2004-02 Supplemental Responses

Table 1: Unit 2 Materials Input

Class	Material	Amount
Coolant	Sump Pool Volume (ft^3)	54,907
Metallic Aluminum	Aluminum Submerged (ft^2)	203
	Aluminum Submerged (lbm)	450
	Aluminum Not-Submerged (ft^2)	1,146
	Aluminum Not-Submerged (lbm)	2,547
Calcium Silicate	CalSil Insulation(ft^3)	0
	Asbestos Insulation (ft^3)	0
	Kaylo Insulation (ft^3)	0
	Unibestos Insulation (ft^3)	0
E-glass	Fiberglass Insulation (ft^3)	6.25*
	NUKON (ft^3)	0
	Temp-Mat (ft^3)	0
	Thermal Wrap (ft^3)	0
Silica Powder	Microtherm (ft^3)	0
	Min-K (ft^3)	0
Mineral Wool	Min-Wool (ft^3)	0
	Rock Wool (ft^3)	0
Aluminum Silicate	3M-200C (ft^3)	0.00
	FiberFrax Durablanket (ft^3)	0
	Kaowool (ft^3)	0
	Mat-Ceramic (ft^3)	0
	Mineral Fiber (ft^3)	0
	PAROC Mineral Wool (ft^3)	0
Concrete	Concrete (ft^2 surface area)	20,000
Buffering Agent	Sodium Tetraborate (lbm)	0
Interam	Interam (ft^3)	0

* Latent fiber is characterized as fiberglass.

Supplemental Response to Address GL 2004-02 Actions at Unit 2
Using Revised Content Guide for GL 2004-02 Supplemental Responses

Table 2 shows the "Time Temperature pH Input" worksheet from the chemical effects model. The sump pH increased to a maximum pH of 8.2 from a minimum pH of 4.1 during the 30 days evaluated, and from the time of recirculation, the spray pH values were assumed to equal the sump pH values. This is conservative because higher pH values are expected to generate more precipitates. This evaluation was performed with spray inputs up to 240 hours post-LOCA.

Table 2: Time Temperature pH Input

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Spray pH	Containment Temp. for Spray (°F)
6	0.1	0.0	0.00	4.1	190	4.1	94
30	0.5	0.0	0.00	4.1	189	4.1	90
60	1.0	0.0	0.00	4.1	188	4.1	87
120	2.0	0.0	0.00	4.1	184	4.1	89
180	3.0	0.1	0.00	4.1	181	4.1	91
200	3.3	0.1	0.00	4.1	180	4.1	92
400	6.7	0.1	0.00	4.1	172	4.1	104
600	10.0	0.2	0.01	5.5	167	4.1	105
800	13.3	0.2	0.01	5.5	164	4.1	107
1000	16.7	0.3	0.01	5.5	163	4.1	108
1200	20.0	0.3	0.01	5.5	162	4.1	108
1400	23.3	0.4	0.02	5.5	161	8.2	108
1600	26.7	0.4	0.02	8.2	160	8.2	108
1800	30.0	0.5	0.02	8.2	158	8.2	108
3200	53.3	0.9	0.04	8.2	144	8.2	113
4600	76.7	1.3	0.05	8.2	137	8.2	147
6000	100.0	1.7	0.07	8.2	141	8.2	153
7400	123.3	2.1	0.09	8.2	144	8.2	155
8800	146.7	2.4	0.10	8.2	146	8.2	155
10200	170.0	2.8	0.12	8.2	147	8.2	154
11600	193.3	3.2	0.13	8.2	148	8.2	154
13000	216.7	3.6	0.15	8.2	149	8.2	154
14400	240.0	4.0	0.17	8.2	149	8.2	154
46400	773.3	12.9	0.54	8.2	139	8.2	141

Table 2: Time Temperature pH Input

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Spray pH	Containment Temp. for Spray (°F)
86400	1440.0	24.0	1.00	8.2	131	8.2	133
172800	2880.0	48.0	2.00	8.2	123	8.2	125
259200	4320.0	72.0	3.00	8.2	119	8.2	121
345600	5760.0	96.0	4.00	8.2	116	8.2	118
432000	7200.0	120.0	5.00	8.2	113	8.2	115
864000	14400.0	240.0	10.00	8.2	107	8.2	108
1296000	21600.0	360.0	15.00	8.2	104	8.2	105
1728000	28800.0	480.0	20.00	8.2	102	8.2	103
2160000	36000.0	600.0	25.00	8.2	101	8.2	102
2592000	43200.0	720.0	30.00	8.2	100	8.2	101

The chemical model calculated the releases from the containment materials based on the temperature and pH conditions of the sump and spray solutions within containment post-LOCA for the recirculation water volume of 54,907 ft^3. The total amount of calcium (Ca), silicon (Si), and aluminum (Al) released based on these inputs is used to determine the amount of precipitates formed from the containment materials as shown in Table 3.

Table 3: Material Release and Precipitate Formation

	Releases by Material (kg)			Precipitates by Material (kg)		
Material Class	Ca	Si	Al	$Ca_3(PO_4)_2$	$NaAlSi_3O_8$	AlOOH
Metallic Aluminum Submerged	0.00	0.00	0.62	0.00	0.31	1.23
Metallic Aluminum Not-Submerged	0.00	0.00	3.74	0.00	1.89	7.44
Calcium Silicate	0.00	0.00	0.00	0.00	0.00	0.00
E-Glass	0.15	1.33	0.00	0.00	2.08	0.00
Silica Powder	0.00	0.00	0.00	0.00	0.00	0.00
Mineral Wool	0.00	0.00	0.00	0.00	0.00	0.00
Aluminum silicate	0.00	0.00	0.00	0.00	0.00	0.00
Concrete	0.14	0.09	0.00	0.00	0.13	0.00
Interam	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.29**	**1.42**	**4.36**	**0.00**	**4.41**	**8.67**

For WBN, sodium aluminum silicate ($NaAlSi_30_8$) and AlOOH precipitates are the major products of the chemical model evaluation. $NaAlSi_30_8$ is formed from the release of silica from latent fiber sources and aluminum from either aluminum metal or fibrous insulation. $NaAlSi_30_8$ precipitate was limited by the latent fiber source term. The remainder of the aluminum released formed ALOOH. The low total amount of aluminum released was due to both the moderate pH and low temperatures of the sump and spray solutions, and the major source of aluminum released in containment for WBN was the aluminum metal exposed to the spray. No calcium phosphate ($Ca_3(PO_4)_2$) precipitate formed due to the absence of trisodium phosphate (TSP) which the available phosphate would react with the calcium released from the E-glass insulation (latent fiber) and concrete.

Therefore, with the small amount of containment materials, the moderate pH, low temperatures, and the current buffering agent the predicted total amount of precipitates formed for WBN over the 30-day period was 13.08 kg as shown in Table 4.

Table 4: Predicted Chemical Precipitate Formation for WBN

Precipitates	kg
$NaAlSi_3O_8$	4.41
AlOOH	8.67
$Ca_3(PO_4)_2$	0.00
Total	**13.08**

3.p. **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.

Provide the information requested in GL 04-02 Requested Information Item 2(e) regarding changes to the plant licensing basis. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

GL 2004-02 Requested Information Item 2(e)

A general description of and planned schedule for any changes to the plant licensing basis resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.

TVA Response

The design basis of the modified emergency sump strainer has been incorporated into the plant's current licensing basis. The WBN Unit 2 FSAR will be amended to include this information prior to fuel load.

Enclosure 2

Unit 1 NRC Audit Open Items With Unit 2 Responses

The following information is provided relative to Unit 1 open items from the NRC audit of the WBN GL 2004-02 resolution that are applicable to Unit 2 (Report ADAMS Accession No. ML062120469), Reference 8.

Open Item 1 *The licensee should submit the final debris generation calculation to verify that the impact of the revised debris quantities has been adequately addressed.*

TVA Response

Calculation MDQ00200020110377, Rev. 0, "Watts Bar Unit 2 Reactor Building GSI-191 Debris Generation Calculation," is provided as Attachment 1 to Enclosure 2. WBN Unit 1 report ALION-CAL-TVA-2739-03, Rev 3, "Watts Bar Reactor Building GSI-191 Debris Generation Calculation," was submitted as Attachment 1 to Reference 3. The Unit 2 calculation is based on the Unit 1 report with the exception that Unit 2 will not use Min-k or 3M fire-wrap and the RMI design differences are addressed.

Open Item 2 *The licensee should submit the final debris generation calculation that addresses crediting debris shielding by robust barriers.*

TVA Response

Credit for shielding by robust barriers is described in the debris generation analysis described in the response to ***Open Item 1***.

Open Item 3 *The licensee should complete the walkdown and the confirmatory analysis to show that the assumptions regarding the amount of latent debris are valid.*

TVA Response

The Unit 1 walkdown for latent debris was completed; it verified that the assumptions used in the debris generation analysis were conservative as described above. The latent debris walkdown final report is contained in WAT-D-11530, "WBN Unit 1, Containment Latent Debris Walkdown, Transmittal of the Final Report for Containment Latent Debris Walkdown," (LTR-CSA-06-74, Proprietary). As described in the response to ***Item 1.*** in Enclosure 1, a similar confirmatory walkdown for loose debris will be performed on Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup.

Open Item 4 *The licensee should provide additional justification for the conclusion that the maximum head loss across the new strainer is less than the NPSH margin available.*

TVA Response

Testing and analysis was used to determine the maximum head loss across the new strainers and that adequate NPSH margin was available. The testing data used includes the July 2010 results. The maximum head loss across the Unit 2 strainer is 1.428 ft. The minimum excess NPSH available (assuming the maximum strainer head loss) is 10.5 feet for the RHR system and 4.8 ft for the CS system.

Open Item 5 *The licensee should provide the final structural analysis report for the replacement strainer.*

TVA Response

The final structural analyses were provided as Attachments to Reference 3 and have since been updated to include Unit 2 as discussed in the response to ***Section 3.k.*** of Enclosure 1. These include calculations PCI-5464-S01, Revision 3, "Structural Evaluation of Advanced Design Containment Building Sump Strainers," and PCI-5464-S02, Revision 3, "Structural Evaluation of Advanced Design Containment Building Sump Strainer Plenum."

Open Item 6 *Upon the completion of PWROG generic methodology development and NRC's approval, the licensee should evaluate the effects of plate out or local deposition of materials concentrated within the reactor core on core heat transfer during the long-term cooling period and submit the results for staff's review.*

TVA Response

NRC evaluation of WCAP-16793-NP for issuance of an SER is ongoing. A comparison of the chemical effects source term loading for WBN is less limiting than the chemical loading debris conditions used for the example case from WCAP 16793-NP, Section 5.7, "Example Run of LOCADM Model" as shown in the table below. The limited quantity of source term material available for dissolution and subsequent deposition in the core is also confirmed by the WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," chemical effects calculations for WBN.

WCAP-16793 Example Conditions	WBN Conditions	Comments
fiberglass debris (7000 ft^3)	6.25 ft^3 fiber	Fiber mass quantities converted to Nukon equivalent volume based upon worst case sources of debris from all 4 loops. See the response to ***Item 3.b.4.*** in Enclosure 1.
calcium silicate debris (80 ft^3)	No Cal-Sil	WBN only has 37 ft^3 of Aluminum Silicate and 1.29 ft^3 of silica available for dissolution
HLSO time (13 hrs)	3 hrs	Longer time to HLSO is more limiting - allows more deposition to occur.

Open Item 7 *The licensee should address the fact that following a large hot leg break, a debris bed might form at the entrance to the core which would be greater than the licensee's acceptance criterion of 0.125 inches and evaluate the impact on the core heat transfer.*

TVA Response

See the response to Item 3.n in Enclosure 1.

Open Item 8 *The licensee should identify any analysis methods, assumptions, and downstream components, which may be affected by changes to WCAP-16406-P and need to be revisited, and verify the components still applicable criteria.*

TVA Response

See the response to item 3.m in Enclosure 1.

Open Item 9 *The licensee should re-evaluate the basis for the estimate of latent fibrous screen penetration to ensure that the estimate is adequately conservative.*

TVA Response

Fibrous debris ingestion downstream effects were based on Calculation MDQ00200020110377, Watts Bar Unit 2 Reactor Building GSI-191 Debris Generation and WCAP-16406-P. A calculation for downstream debris concentration was performed for Unit 2. The downstream debris concentration is 835 ppm and the latent debris concentration is 1 ppm.

Open Item 10 *The licensee should provide justification for the conclusion that epoxy phenolic coating is resistant to leaching in the WBN post-LOCA environment. In addition, although the WBN alkyd coatings are already considered in the debris term, the evaluation of alkyd coating should include an understanding of how this coating interacts with the projected post-LOCA environment.*

TVA Response

The epoxy leaching issue was addressed generically in PWROG letter OG-07-129 concerning NRC RAIs for WCAP-16530, "Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191." Originally, the question was posed as RAI #13 on the document and then additional information was requested in a second set of RAIs as RAI #2. Although the example calculations performed for RAI #2 in the PWROG response were for a dry containment, the values are not significantly different for an ice condenser containment (order of magnitude). The volumetric concentration of chlorides from leaching was shown to be relatively low and insignificant as a chemical reactant as would be expected for WBN.

The question on alkyd coatings was addressed in WCAP-16793-NP, Revision 0, Section 2.5.2. Here it is stated that, "...these coatings are, as a class, chemically benign and do not react to the post-LOCA sump fluid. In the case of alkyds, the coating would break down into oligomeric carboxylate salts and glycol. The oligomeric carboxylate salts would actually tend to inhibit the formation of precipitates. However, since the amount of alkyds inside containment is small, and the salts are expected to be altered by radiolysis, no credit is taken for their presence inside containment. For these reasons, these non epoxy coatings are evaluated to have a negligible effect on post-LOCA chemical precipitant production and are therefore not a concern with respect to long-term cooling."

Open Item 11 *WBN indicated that the WCAP-16530-NP chemical model spreadsheet contained an error that affected the amount of chemical precipitate for WBN. The licensee should provide an evaluation of the plant specific impact of any changes to the WCAP chemical model in the WBN GL 2004-02 response supplement.*

TVA Response

The Unit 2 evaluation was performed with the corrected spreadsheet and is described in ***Item 3.0.1*** in Enclosure 1.

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) N/A

Calc Title:
Watts Bar Unit 2 Reactor Building GSI-191 Debris Generation Calculation

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC						
NEW	CN	NUC	WBN	MEB	MDQ00200020110377	N/A	000	Entire calc ☒ Selected pages ☐

ACTION	NEW ☒ REVISION ☐	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
002	000	WB-DC-40-5 and NEI-04-07

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
N/A	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
HChen	423-365-1962	Bechtel MEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
HChen *[signature]*	2/7/2011	RCWhite *R. White*	2-7-11
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
RCWhite *R. White*	2-7-11	for D.F. Helms *[signature]*	2-9-11

STATEMENT OF PROBLEM/ABSTRACT

The purpose of this calculation is to determine the type, quantity, and size distribution of debris that would be generated should a high energy line break requiring recirculation through the emergency sump ever occur at Watts Bar Unit 2. Similarity analysis was made for Unit 2 containment debris generation based on Unit 1 debris generation report (Alion-CAL-TVA-2739-03 Rev.4). The output of this calculation may be used to determine the types and overall quantity of debris that could reach the Watts Bar Unit 2 sump screens.

Special Requirements and /or Limiting Conditions:
The Unit 2 Containment insulation, debris and cleanliness from Unit 2 Walkdown package must remained bounded by Unit 1 containment conditions.

LEGIBILITY EVALUATED AND ACCEPTED FOR ISSUE. ALL PAGES
Scott Helms 2/8/11
SIGNATURE REV 0 DATE

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: EQB 1M - WBN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	MEB	MDQ00200020110377	000

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☐
02	NA	N/A	NA	Bechtel	

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	REACTOR BLDG	A	ECCS
A	HELB	A	LOCA
A	PIPE RUPTURE	A	PIPE BREAK
A	STRAINER		

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	VD	WBN	MEB	ALION-CAL-TVA-2739-03	
A	P	VD	WBN	MEB	LTR-CSA-06-74	
A	P	TN	WBN	MEB	25402-011-3PS-NNP0-00001	
A	P	DG	WBN	MEB	NEI-04-07	
A	P	VD	WBN	MEB	25402-011-V1A-NNP0-00153-001	
A	P	DC	WBN	MEB	WB-DC-40-5	
A	P	VD	WBN	MEB	66-9144025-000	
A	S	CN	WBN	MEB	MDQ00107220060104	

CCRIS ONLY UPDATES:

Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER MDQ00200020110377 Page i3

Title	Watts Bar Unit 2 Reactor Building GSI-191 Debris Generation Calculation
Revision No.	**DESCRIPTION OF REVISION**
000	Initial issue to determine the type, quantity, and size distribution of debris that would be generated should a high energy line break requiring recirculation through the emergency sump ever occur at Watts Bar Unit 2. A WITEL punchlist # PL-11-3555 was created to track the Westinghouse insulation inventory and latent debris walkdowns and assure that the Unit 2 Containment insulation, debris and cleanliness from Unit 2 walkdown package are bounded by Unit 1 containment conditions. Successor calculation MDQ00107220060104 needs to be revised accordingly. The effect of Unit 2/dual unit operation on Unit 1 margins has been reviewed with no impact. Ultimate heat sink (UHS) temperature was not used as an input to the calculation analyses. Therefore, existing calculation results will not be affected by changing the UHS technical specification temperature. FSAR AND TECHNICAL SPECIFICATIONS HAVE BEEN REVIEWED AND ARE NOT AFFECTED BY THIS REVISION OF THE CALCULATION. Reviewer: JHKarwik 2/8/2011 J.H. KARWIK Pages Added: All pages – initial issue Total number of pages in this revision including Attachments: 10 Pages

NPG CALCULATION VERIFICATION FORM

Calculation Identifier MDQ00200020110377
R000

Method of verification used:	
1. Design Review ☒	Verifier R.C. White Date
2. Alternate Calculation ☐	R. White 2-7-11
3. Qualification Test ☐	

Comments:

The changes to the calculation described in the Record of Revision for the current revision have been reviewed and have been found to be technically adequate in format and content.

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: MDQ00200020110377	Revision:	000

TABLE OF CONTENTS

1. Purpose

The purpose of this calculation is to determine the type, quantity, and size distribution of debris that would be generated should a high energy line break requiring recirculation through the emergency sump ever occur at Watts Bar Unit 2. This calculation is based on a similarity analysis from the Unit 1 debris generation report (ALION-CAL-TVA-2739-03 Rev.4, Ref. 2.1). The output of this calculation may be used to determine the types and overall quantity of debris that could reach the Watts Bar Unit 2 sump screens.

2. References

2.1 Alion Calculation, ALION-CAL-TVA-2739-03, Rev. 004, Watts Bar Reactor Building GSI-191 Debris Generation Calculation.

2.2 Westinghouse letter, LTR-CSA-06-74, Watts Bar Latent Debris Survey (Included in Ref.2.1).

2.3 Transco Test Report, 25402-011-V1A-NNP0-00153-001, Thermal Performance of 4 5/8" Nominal Thickness Reflective Insulation Specimen, July 28, 2010.

2.4 NRC Safety Evaluation Report, NEI-04-07, Volume 2, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report 'Pressurized Water Reactor Sump Performance Evaluation Methodology'", Rev. 0, December 2004.

2.5 Technical specification No.25402-011-3PS-NNP0-00001, Rev.002, Furnishing and Installing Metal Reflective Insulation for the Watts Bar Unit 2 Construction Completion Project.

2.6 TVA Design Criteria, WB-DC-40-5, Rev.004, Insulation- (Unit 1/Unit 2).

2.7 AREVA Document No.66-9144025-000, Watts Bar Unit 1 ECCS strainer performance test report, 09/21/2009.

3. Design Input Data

This section lists the design inputs used to determine the types, quantity, and representative size distribution of debris generated by a postulated break.

3.1. Unit 1 debris generation report

Alion report (ALION-CAL-TVA-2739-03 Rev.4, Ref.2.1) did a detailed analysis on Watts Bar Unit 1 Reactor Building GSI-191 debris generation. The worst case LBLOCA location and corresponding debris generation were considered for all 4 loops. Three primary types of potential debris generation during the worst case break in containment buildings (insulation, coatings, and latent debris) were analyzed together with an AutoCAD model and Unit 1 walkdown data. Considering that Unit 2 is mirror image of Unit 1, the Alion report was used as the base to estimate the debris generation in Unit 2 Reactor Building. All of different type of debris loading from the Alion report was justified through the similarity analysis between Units 1 and 2. See the detailed information in Section 6.

3.2. Insulation

3.2.1. Transco Reflective Metal Insulation design for Unit 2

According to the test report for Transco RMI (Ref.2.3), the 4-5/8 in nominal thickness test specimen consisted 24 gauge stainless steel inner and outer sheets enclosing 14 layers of waffled 0.0002 in thickness stainless foil and a vertical joint, which is about 3 foils per inch thickness. This is similar to Diamond RMI which used for Unit 1.

3.2.2. Min-K and 3M-M20C

There is no insulation of Min-K and 3M-M20C for Unit 2. All of components with Min-K and 3M-M20C will be replaced with RMI.

3.3. Coating

Unit 2 coatings in Reactor Building are similar to those for Unit 1. Essentially all steel surfaces at Watts Bar are coated with Carbozinc™ 11, inorganic zinc (IOZ) primer. All steel 6 feet from the containment floor has also been topcoated with Phenoline™ 305. The containment liner is also coated with Carbozinc™ 11 and has been left without a topcoat. The concrete floors and walls have been painted with Phenoline™ 305. All concrete below 6 feet has been painted with a Carboline™ 295 surfacer and then painted with two coats of Phenoline 305™. The steam generators are coated with Carboline™ 4674 underneath the RMI insulation.
See the detailed information for the properties of coatings in Ref.2.1.

3.4. Latent Debris

A total 100 lbs latent Debris was considered for Unit 2. A latent debris survey was completed at Watts Bar Unit 1 on 09/06 [Ref. 2.2]. It indicated a total latent debris load of 69.2 lbs. 100 lbs of latent debris was used in the Unit 1 strainer performance test (Ref.2.7, Test 4C). According to SER Section 3.5.2.3 (Ref. 2.4) suggests that 15% of the latent debris should be assumed to be fiber, and the other 85% particulate. Thus, 85 lb was assumed to be dirt/dust and the remaining 15 lb was assumed to be latent fiber. Special requirement in Section 5.0 will assure this value is conservative.

4. Assumptions

4.1 Justified Assumption

4.1.1 The break locations and zone of influence (ZOI) in Unit 2 containment are similar to those of Unit 1.

Justification: Considering that Unit 2 containment geometry configuration is a mirror image of Unit 1, the postulated break is assumed in the same location as Unit 1 with same size ZOI is reasonable.

4.1.2 The Unit 1 Enercon Insulation Walkdown Report (Attachment A, Ref.2.1) was used to identify and locate the quantities of insulation in lower containment for Unit 2.

Justification: Per Ref.2.5, the insulation system of Unit 2 components in Reactor Building is based on 80 Btu/hr ft^2. The insulation system of Unit 1 components in Reactor Building is based on 65 Btu/hr ft^2 according to Ref.2.6. Overall, Unit 2 RMI insulation thickness is thinner and the weight is lighter than that for Unit 1 RMI design. Therefore, it is reasonable to assume that results from Unit 1 Enercon Insulation Walkdown Report bounds those for Unit 2 insulation walkdown report.

4.1.3 The surface area of RMI used to replace Min-K and 3M-M20C is neglected in this calculation.

Justification: Based on the review of Unit 1 Enercon Walkdown Report (Attachment A, Ref.2.1), the total volume of Min-K and 3M-M20C needed to be replaced in Unit 2 with RMI is insignificant comparing the total volume RMI. The quantity of heavier unit weight Unit 1 RMI exceeds the larger quantity (which includes the small amount of Min-K and 3M-M20C replaced with RMI) of lighter unit weight Unit 2 RMI.

4.1.4 The debris load from coating during postulated LBLOCA for Unit 1 is the same as that of Unit 1.

Justification: Since Unit 2 coatings in Reactor Building are similar to those for Unit 1, it is reasonable to assume that Unit 2 has the same debris load from coating.

4.2 Unverified Assumptions

None.

5. Special Requirements/Limiting Conditions

The Unit 2 Containment insulation, debris and cleanliness from Unit 2 Walkdown package must remained bounded by Unit 1 containment conditions.

6. Computations and Analyses

Four LBLOCA case in different Loops were considered in Alion Unit 1 debris generation calculation. For each case, the detailed analysis was made for each type of debris load. The maximum debris loads for each type of debris in the four cases were used for Unit 2 debris load.

6.1 Insulation

Since there is no Min-K and 3M-M20C for Unit 2 insulation, the data listed in summary Table 6.1 to 6.4 in Section 6 of Ref. 2.1 was not used. The total maximum surface area of RMI is 101,202 ft^2 with 75902 ft^2 (75%) in small pieces and 25300 ft^2 (25%) in large pieces. Here, the surface area of RMI to replace Min-K and 3M-M20C for Unit 2 is negligible (Assumption 4.1.3).

6.2 Coating

Unit 2 coatings in Reactor Building are similar to those for Unit 1. Based on the data listed in summary Table 6.1 to 6.4 in Section 6 of Ref. 2.1, the maximum debris loads for the coatings are 149 lb for Phenolic Paint, 1161 lb for Inorganic zinc, 44 lb for Alkyd Paint, 25 lb for Epoxy Paint, 836 lb for Carboline 295, and 49 lb for Silicone Paint.

6.3 Latent debris

Total latent Debris is 100 lbs (Section 3.4). The fiber is 15 lb (6.25 ft^3) and dirt/dust is 85 lb.

7. Supporting Graphics

None.

8. Summary of Results

Table 1 summarizes the detailed debris load for Watts Bar Unit 2. The detailed properties of these debris loads can be found in Table 6.5 of Ref. 2.1.

Table 1 Debris Load during LBLOCA in Unit 2 Reactor Building

Debris Type	**Small Pieces**	**Large Pieces**	**Total**
Stainless Steel RMI	75,902 ft^2 (75%)	25,300 ft^2 (25%)	101,202 ft^2
Debris Type	**Fines**	**Large Pieces**	**Total**
Latent Fiber	6.25 ft^3	0 ft^3	6.25 ft^3
Debris Type	**Fines**	**Chips**	**Total**
Dirt/Dust	85 lb	0 lb	85 lb
Phenolic Paint	149 lb	0 lb	149 lb
IOZ Paint	1,161 lb	0 lb	1,161 lb
Alkyd Paint	44 lb	0 lb	44 lb
Epoxy Paint	25 lb	0 lb	25 lb
Carboline 295	836 lb	0 lb	836 lb
Silicone Paint	49 lb	0 lb	49 lb

9. Conclusions

The debris loads generated during a high energy line break in Unit 2 Reactor Building is established according to Unit 1 debris generation report (ALION-CAL-TVA-2739-03 Rev.4, Ref. 2.1). The detailed debris generation data for each type debris load were summarized in Table 1. The output of this calculation may be used for future Watts Bar Unit 2 sump strainer analysis.

Enclosure 3

RAIs From Unit 1's RAI Supplemental Response to GL 2004-02 With Unit 2 Responses

RAI 1. *Please provide a summary description of the reports for the tests conducted that justified the ZOI reductions for banded Min-K and the 3M-M20C fire barrier material. This information should include the materials used in the testing, geometries of the targets, and materials used for banding and jackets. Provide information that compares the sizes of the test targets and the potential targets in the plant, and how any differences in sizing affect the ability of the insulation systems to resist damage from steam impingement. Please state whether the testing in WCAP-16783, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and 3M M20C Fire Barrier Insulation for Watts Bar Nuclear Plant," was specific to the Watts Bar insulation systems. If not, please provide information that shows that the Watts Bar 1 banding systems are at least as structurally robust as the system that was used in the testing.*

TVA Response

Unit 2 will not have Min-K nor 3M-M20C fire barrier material or any similar fibrous insulation or fire barrier material inside containment. This item is not applicable to Unit 2.

RAI 2. *Based upon the information provided for the audit review, the 3M M20C radiant energy barrier material was considered to be a fiberglass-type material. The supplemental response revises this information, identifying that the 3M M20C material actually contains a significant fraction of vermiculite particulate. Based on the properties of vermiculite, which contains silicon dioxide (SiO_2), as does Min-K and Microtherm insulations materials, the staff believe that debris from the 3M M20C material could have a significant impact on strainer head loss, rather than behaving predominately as fibrous insulation material. Please provide a basis to support the conclusion that the revisions made to the assumed characteristics of 3M M20C do not affect the conclusions of the strainer performance analysis*

TVA Response

Unit 2 will not have 3M-M20C fire barrier material or any similar fibrous insulation or fire barrier material inside containment. This item is not applicable to Unit 2.

RAI 3. *Please provide a technically defensible head loss evaluation for the strainer that is based on NRC-accepted testing or analysis techniques. The licensee should reference the staff's Watts Bar 1 audit report (ADAMS Accession No. ML062120461) for specific issues with Watts Bar 1 head loss testing. Further, the licensee should reference the staff's review guidance for head loss and vortexing (ADAMS Accession No. ML080230038) for acceptable testing procedures.*

TVA Response

Additional tests were conducted in July 2010 on the Unit 1 strainer configurations. This testing incorporated NRC accepted techniques. The tests are applicable to the Unit 2 strainers.

The tests were performed in a tank incorporating the test protocols summarized in Attachment 1 to this enclosure.

Flume Velocity and Turbulence

The test tank does not credit near-field settling and utilizes a perforated floor and mechanical mixers to ensure debris remains suspended. This change in protocol eliminates the need to compare the test tank velocities to the plant containment velocities because debris is maintained in a suspended condition for transport.

Near-Field Settling

The near-field settling is addressed since the test tank is designed to keep debris in suspension and available for transport.

Debris Addition to the Test Flume

Utilizing the test tank protocol, the following steps are expected to address this section:

- The test tank was filled with water to the design-basis water level and maintained during the duration of the test.
- Fine fiber was shredded by a food processor, Munson shredder, or other type of device to achieve the same form of fines as discussed in NUREG/CR-6885, "Screen Penetration Test Report." The fine fibers were then diluted with enough water such that no clumps will be visually observed.
- The debris was introduced into the test tank only after the start of the recirculation pump and the designed flow rate has been established. Debris was sequenced with the most transportable debris introduced first followed by the next most transportable, and so on, until all debris is sequenced into the test tank.
- Debris was mixed with heated water with a ratio of 5:1 to ensure debris does not agglomerate. See Attachments 2 and 3 to this enclosure for further discussion of debris preparation and debris dilution to minimize agglomeration.
- A trash pump was utilized to inject the debris into the test tank below the water surface to ensure there is no air entrainment during debris introduction.

Head Loss Termination Criteria

The termination criteria for testing are summarized below:

- Fifteen (15) test tank turnovers shall occur following the completion of the last batch of debris.
- Following the 15 turnovers, the test may be terminated only if the percent change in head loss over the last 30-minute average is less than 1%.

RAI 4. *For one SBLOCA case, the tall strainer modules are not expected to be fully submerged in the sump pool. Please provide an evaluation that shows that vortexing or air ingestion will not occur when strainer modules are not fully submerged.*

TVA Response

The minimum submergence of the WBN containment sump strainer under LBLOCA and SBLOCA conditions occurs at the time of initial recirculation operation. Calculation revisions for minimum sump water level confirmed that strainer submergence is demonstrated for all operating conditions. Refer to the response to ***Item 3.f.2.*** in Enclosure 1.

Air Ingestion

The above evaluation specifically addressed the issue of vortex formation associated with the WBN strainer. It was concluded that vortex would not occur due to the physical configuration of the WBN strainer and sump design.

RAI 5. *Please provide information that shows that the clean strainer head loss (CSHL) correlation used to determine the Watts Bar CSHL is valid. The licensee's testing organization relied on a clean strainer head loss correlation based on prototype BWR strainer testing, although BWR strainers have a significantly different geometry from PWR strainers [The staff is currently reviewing CSHL test data and calculations received from Performance Contracting, Incorporated (PCI) which may or may not resolve this issue.]*

TVA Response

As discussed in the response to ***Item 3.f.9.*** in Enclosure 1, the clean strainer head loss across the WBN strainer assemblies was based in part on prototype strainer head loss test data. The Boiling Water Reactor Owners Group (BWROG) performed testing on a number of advanced design containment sump strainers at the Electric Power Research Institute (EPRI) Charlotte Non-Destructive Examination Facility in 1995. Included in the testing was a prototype "stacked disc" strainer designed and manufactured by PCI. This testing established that the clean strainer head loss for the basic PCI strainer design is a function of: (1) the kinematic viscosity of water (a function of water temperature), and (2) the strainer exit velocity (a function of strainer flow rate and exit area). Based on the test results, the following relationship was established for the PCI clean strainer head loss for strainer assemblies.

$$HL_{strainer} = K_1\ Y\ V_{exit} + K_2\ (V_{exit}^2 / 2g)$$

Where

Y = kinematic viscosity of water, ft^2/sec (a function of water temperature)

g = gravitational constant ($32.2\ ft/sec^2$)

V_{exit} = strainer exit velocity, ft/sec (determined by dividing the strainer flow rate by the exit area defined as the cross sectional area of the strainer central flow channel)

K_1 = 1,024 (coefficient determined by regression analysis of test data)

K_2 = 0.8792 (coefficient determined by regression analysis of test data)

To confirm the applicability of this head loss relationship to strainers designed for PWR service, PCI fabricated a series of prototype strainers with internal flow channels consistent with a range of PWR service conditions and physical configuration constraints. These prototype strainers were tested for clean strainer head loss at Alden Research Laboratory (ARL). The clean strainer test results were compared to those calculated using the clean strainer head loss relationship established from the earlier testing to ensure that the calculated clean strainer head loss values conservatively bounded the measured values. For a strainer comparable to those provided for Unit 2, the test results were as follows:

Table 1: Clean Strainer Head Loss Calculated vs. ARL Test Data

Test Flow Rate (in gpm)	Calculated Head Loss (in ft. of water)	Measured Head Loss (in ft. of water)
40.52	0.011	0.0101
60.78	0.018	0.0137
76.95	0.025	0.0202
100.66	0.036	0.0284
120.99	0.048	0.0385

As shown above, the PCI clean strainer regression equation developed from the BWROG testing provides comparable and conservatively bounding results for the tested strainer.

Recognizing that the single most important variable in establishing the calculated head loss value using the PCI equation is exit velocity, the exit velocity used in the 1995 BWROG testing was compared to WBN service conditions. The strainer exit velocity for the test prototype was 7.723 ft/sec. The limiting exit velocity for the WBN strainers is 2.093 ft/sec. Because the WBN strainer exit velocity is less than that for the tested prototype, the WBN calculated values contain an additional measure of conservatism.

The PCI clean strainer head loss equation cited above (with an additional 6% margin applied to bound test measurement uncertainty) was used to establish the nominal head loss across the WBN strainers. The nominal head loss was then adjusted to conservatively account for additional head losses associated with specific aspects of the WBN design including (1) strainer length, (2) strainer discharge to the flow plenum, and (3) flow plenum discharge to the sump pit. These additional head losses were based on a conservative application of standard hydraulic analysis techniques and did not use any information developed from the BWROG strainer testing.

RAI 6. *Please provide an updated maximum postulated strainer head loss (debris and clean strainer) based on recent re-calculations which may result from consideration of this*

RAI set. Please provide the assumptions that support the updated maximum postulated head loss value. As appropriate, please provide a revised evaluation of flashing across the debris bed and strainer.

TVA Response

Additional tests were conducted in July 2010 on the Unit 1 strainer configurations. These tests further evaluated the performance of the advanced strainer design. The Unit 2 strainer geometry closely resembles the Unit 1 strainer element configuration with the exception that the core tube diameter is larger in the Unit 2 strainer modules, which is more conservative. Refer to the response to ***Item 3.f.10.*** in Enclosure 1 for the Unit 2 Debris Laden Containment Sump Strainer Head Loss Summary. Containment accident pressure is not credited to preclude flashing. Further, the maximum sump water temperature of 190°F provides subcooling margin to preclude flashing. The minimum containment pressure assumed is 14.3 psia. The vapor pressure at the maximum containment sump temperature of 190°F is 9.34 psia. Thus, 4.96 psi 11.8 ft head loss margin exists across the strainer before flashing could occur. The total strainer head loss of 1.428 ft at LBLOCA design flow is bounded.

RAI 7. *Please verify whether Nukon thermal insulation material or Interam fire barrier material was used during testing. If Nukon was used as a surrogate for fire barrier material, please justify such use as being prototypical or conservative.*

TVA Response

Unit 2 will not have Min-K nor 3M-M20C fire barrier material or any similar fibrous insulation or fire barrier material inside containment. This item is not applicable to Unit 2.

RAI 8. *The small-break LOCA (SBLOCA) water level calculation credits a significant volume of water from the RCS (42,810 gallons) as contributing to the containment pool. The staff questions whether this assumption envelops the most limiting SBLOCA conditions, with respect to both break location and timing during the accident response sequence. For example, although outflow from a break near the top of the pressurizer would contribute to the formation of the containment pool, as time passes, the inflow into the RCS from the ECCS could meet and/or exceed the outflow in many possible SBLOCA scenarios, particularly as operators cool down and depressurize the plant. As a result, for such SBLOCA conditions, shrinkage of the RCS inventory and refill of the pressurizer steam space could actually lead to the net result of the RCS holding up inventory from the containment pool, rather than contributing to it. Since the depletion of the RWST could occur over an extended period of time for a small-break LOCA, the RCS may act as a net hold up volume at switchover to recirculation or at subsequent times during the recirculation phase of the LOCA. Please provide the technical basis for considering a contribution from the RCS of 42,810 gallons in determining a conservative minimum water level for analyzing sump performance under small-break LOCA conditions.*

TVA Response

Certain SBLOCA scenarios involve the inadvertent opening of the pressurizer code safety valves or Power Operated Relief Valves (PORVs) to the pressurizer relief tank. However, since the pressurizer code safety/PORV nozzles are located at the highest point in the RCS, the plant would most likely be cooled down and depressurized, and pressurizer level reduced to below the PORV/safety nozzles (in this case, stopping the leak) long before recirculation would be required. Thus, these scenarios need not be considered. The SBLOCA scenario that includes stuck open pressurizer valves is not considered because operator actions are required to verify that all pressurizer PORVs are closed. If the PORVs are not closed, operator actions are required to close the pressurizer PORV or associated block valve when RCS pressure is less than 2,235 psig. If the valve is not able to be isolated, the event is no longer an RCS depressurization but an SBLOCA. The long-term plant response due to an unisolable valve opening is bounded by the limiting SBLOCA. This statement was specific to the scenario related to a stuck open pressurizer valve and is not applicable to other SBLOCAs at higher elevations.

The value of 42,810 gallons from the RCS presented in the supplemental response (Reference 3) is the contribution from the RCS to the sump volume based on a 2,000 gpm SBLOCA. This value has been revised to 40,467 gallons. However, the only volume that can get into the Reactor cavity for an SBLOCA is from the RCS leakage. The following scenarios conservatively assume that the initial reactor coolant inventory remains constant and inside the RCS for all break locations. The reactor cavity is assumed to fill only for:

a. a break in the hot or cold leg piping at the reactor vessel to nozzle transition,

b. the rupture of a control rod drive mechanism (CRDM) housing, and

c. when the lower compartment water level reaches El. 715' - 8.5".

The bottom of the hot leg penetrations is El. 715' - 8.5", and the entrance to the keyway is at El. 716' - 0". The reactor vessel nozzles and the CRDM housings are attached to the reactor vessel and located within the reactor cavity area. All other postulated breaks in the Reactor Coolant Pressure Boundary are outside the reactor cavity enclosure. The cases below discuss the assumed holdup values.

WBN calculations conservatively assume that the entire RCS leakage escapes into the cavity and thus is considered as volume holdup. As a net result, RCS volume is not considered as a contributor to sump volume.

Background:

Calculation WBNOSG4071 was provided to the NRC during the NRC Audit of WBN for GL 2004-02. Cases I and II were revised to address RCS shrinkage, and Cases Ia and IIa were added in a later revision and address RCS shrinkage. All 4 cases are summarized below:

Case I: 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), RCS holdup due to fluid shrinkage, Containment Spray (CS) operation on RWST level at Residual Heat Removal (RHR) switchover

The Reactor Building response to an SBLOCA was determined using the MONSTER computer program. The volume of water in the reactor cavity is determined by calculating the time of ECCS switchover to the containment sump and picking the value of the reactor cavity water volume from the computer code output. This resulted in 1,878 gallons in the reactor cavity. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Case II: 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups, RCS holdup due to fluid shrinkage, CS operation on sump, passive failure outside the crane wall, long term level

The volume of water assumed to be held up in the reactor cavity is 2,459 gallons. The fluid head necessary to achieve equilibrium outflow through the penetrations in the reactor shield wall, if all RWST water injected after a LOCA was released within the reactor cavity, was determined. The cavity would fill to the level of the hot and cold leg penetrations, then start to flow out to the lower compartment. The water level in the reactor cavity would continue to rise until the head developed was high enough to achieve an equilibrium water level where the flow in would equal the flow out.

Case Ia.: 2,000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), RCS holdup due to fluid shrinkage, CS operation on RWST, level at RHR switchover

The volume of water assumed to be held up in the reactor cavity is determined by calculating the time of RHR switchover to the containment sump and multiplying the time by 2,000 gpm (RCS leakage rate). Time to RHR switchover was determined to be the time it takes to expend the RWST inventory with two trains of containment spray in operation. This results in a value of 40,467 gallons. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Case IIa.: 2,000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), RCS holdup due to fluid shrinkage, CS operation on sump, level at CS switchover

The volume of water assumed to be held up in the reactor cavity is determined by calculating the time of CS switchover to the containment sump and multiplying the time by 2,000 gpm (RCS leakage rate). Time to CS switchover was determined to be the time it takes to expend the RWST inventory with two trains of containment spray in operation. This results in a value of 60,875 gallons. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Inventory	Volume (gal)			
	Case I	Case Ia	Case II	Case IIa
Water in lower compartment (RWST and ice melt)	193,004		297,265	
Water in reactor cavity (RCS leakage)	1,878	40,467	2,459	60,875
Water in refueling canal (RWST and ice melt)	12,619		13,363	
Ice melt addition to sump		46,516		77,175
RWST addition to containment		202,575		303,585
RCS addition to sump	0	0	0	0
Total inventory	207,501	289,558	313,087	441,635

Holdup	Volume (gal)			
Service	**Case I**	**Case Ia**	**Case II**	**Case IIa**
Containment Spray Piping	1,998	1,998	1,998	1,998
Containment atmosphere @ 250° F as vapor	1,031	1,031	1,031	1,031
as droplets	1,283	1,283	1,283	1,283
Holdup on containment floor	8,500	8,500	8,500	8,500
Refueling canal holdup (drains not submerged)	9,178	9,178	9,178	9,178
Holdup from RCS shrinkage	5,940	16,126	12,148	16,126
Reactor cavity holdup	1,878	40,467	2,459	60,875
Pocket sump	395	395	395	395
RHR sump	5,083	5,083	5,083	5,083
Total Holdup	35,286	84,061	42,075	104,469
Net fluid available to sump	172,215	205,497	271,012	337,166

Sump level (ft)				
	Case I	Case Ia	Case II	Case IIa
Level at RHR switchover	5.78	6.91		
Level at CS switchover			9.39	12.07

RAI 9. *The NRC staff considers in-vessel downstream effects to not be fully addressed at Watts Bar 1, as well as at other PWRs. The Watts Bar 1 fuel and vessel downstream effects analysis is based on WCAP-16406-P-A, Rev.1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," and a comparison of the Watts Bar 1 plant conditions to the conditions evaluated in draft WCAP-16793-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The fuel cladding temperature analysis is based on the sample LOCADM calculation in draft WCAP-16793-NP. However, Condition and Limitation No. 13 of the staff's draft SE on WCAP-16793-NP, Revision 0, requires that the aluminum release rates used in the LOCADM spreadsheet be increased by a factor of two for the initial portion of the LOCA. Therefore, the sample calculation contained in Revision 0 of the WCAP may not reflect maximum cladding temperature. Further, core inlet blockage issues at Watts Bar 1 have not been resolved through application of WCAP -16793-NP, Revision 0. The NRC staff has not issued a final safety evaluation (SE) for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Watts Bar 1 by showing that the Watts Bar 1 plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE on WCAP-16793-NP, and by addressing the conditions and limitations in the final SE. The licensee may alternatively resolve this item by demonstrating, without reference to WCAP-16793-NP or the staff SE, that in-vessel downstream effects have been addressed at Watts Bar 1. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793-NP. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of GSI-191.*

TVA Response

TVA will complete the WBN in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 following issuance of the final NRC SER for Topical Report No. WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." Based on available margins, it is anticipated that the remaining in-vessel downstream effects issues can be addressed by demonstrating that WBN plant-specific conditions are bounded by the evaluation in the final report. Following issuance of the SE, a submittal will be made documenting the final WBN in-vessel downstream effects evaluation.

RAI 10. *Please indicate what aspects of the plant's licensing basis has changed and/or what new information will be added and considered to be part of the plant's licensing basis. Please provide a schedule for establishing a revised licensing basis.*

TVA Response

See the response to ***Item 3.p.*** in Enclosure 1.

Attachment 1 to Enclosure 3

Test Tank Protocol

The following steps provide a general approach used with Sequoyah Nuclear Plant (Unit 1 and Unit 2) and Watts Bar Nuclear Plant (Unit 1) test tank strainer testing.

1. **VERIFY** that the tank, strainer, piping, and test equipment have been set up in accordance with test set up procedure.

2. **PREPARE** the debris according to the following steps unless otherwise indicated by the Test Engineer.

   Note: The non-chemical debris has been prepared by Performance Consulting, Inc. (PCI) in accordance with PCI Technical Document No. SFSS-TD-2007-004; Sure-Flow® Suction Strainer - Testing Debris Preparation and Surrogates and shipped to ALDEN. Changes to this document implemented in the test plan or test(s) shall be documented in the Test Plan with justification, as applicable.

3. **WEIGH** the non-chemical debris dry in accordance with the quantities specified in the debris allocation tables.

4. **ALLOCATE** debris into equal amounts into multiple 5-gallon buckets filling each bucket with no more than 1/6 full of debris. This procedure applies to all fiber and particulate debris.

5. **COMBINE** each batch of the non-chemical debris with water and store for introduction into the test tank in mixing containers. The debris may be "mixed" with hot water (~120 °F) to help remove trapped air from fibrous debris. Use the following steps to mix the debris:

   a. **DILUTE** the debris with hot water (~120 °F) to an approximate ratio of 5 parts water to 1 part debris (by volume).

   b. **MIX** the debris and heated city water in mixing containers.

   c. If needed, Further **DILUTE** the debris to ensure there is no agglomeration.

6. **PREPARE** the chemical debris in accordance with chemical debris procedure.

7. **FILL** the test tank with city water and heat to - 120°F unless specified by the Test Engineer to the target water level (typically the minimum water level for Emergency Core Cooling System recirculation or equivalent).

8. **DOCUMENT** the recirculation water level in the test tank of all tests and manually verify sump strainer submergence depth (if applicable).

9. **BEGIN** performing downstream sampling. Document Sample Rate

10. **START** the test tank recirculation pump and maintain the minimum target flow rate.

11. **MEASURE** and **RECORD** the pH of test tank water.

12. **OBSERVE** the strainer area for vortexing.

13. **OBSERVE** tank mixing energy and confirm applicability to hinder near field settling.

14. **RECORD** the following data at approximately 2-minute intervals.

    NOTE that a computer data acquisition automatically records data at 10 second intervals:

    - Flow rate
    - Water temperature
    - Differential pressure across the strainer module
    - Observations of vortexing at the surface of water near strainer (as specified by the Test Engineer)
    - Observations of bore hole formation (as specified by the Test Engineer)
    - Additional appropriate information

15. **FILL** test tank injection hopper with bypass water from the test loop.

16. **START** debris addition trash pump at slow flow.

17. **INSERT** all of the particulate debris into the pumping receptacle in the order prescribed in the debris allocation table.

18. **RINSE** the bucket(s) with heated city water to ensure that all of the debris has been introduced into the test tank.

19. **INSERT** the fibrous debris into the pumping receptacle in the order prescribed in the debris allocation table.

20. **RINSE** the bucket(s) with heated city water to ensure that all of the debris has been introduced into the test tank.

21. **DISASSEMBLE** the trash pump to ensure all debris has been transferred to the test tank.

22. **INSERT** all debris trapped in the trash pump into the test tank.

23. **MAINTAIN** the recirculation flow rate and MONITOR the head loss across the test strainer for at least five (5) test tank turnovers after 100% of the non-chemical debris has been placed into the test tank.

24. **MEASURE** and **RECORD** the pH of test tank water.

25. **OBSERVE** the strainer area for vortexing and the formation of bore holes.

26. Carefully/slowly **INSERT** the base chemical concentration through a debris introduction downcomer into the test tank unless otherwise specified by the Test Engineer.

Note 1: For tests which require more than one chemical surrogate (i.e., Calcium Phosphate and Aluminum Oxyhydroxide), a minimum of one **(1)** test tank turnover should be allowed between introduction of each chemical precipitate into the test tank.

Note 2: Be sure the water level is managed by the overflow system.

Note 3: MEASURE and RECORD the pH of the test tank water when approximately 25%, 50%, 75%, and 100% of the chemical debris has been added.

27. **MAINTAIN** the recirculation flow rate and MONITOR the head loss across the test strainer for at least two (2) test tank turnovers.

28. **REPEAT** chemical addition procedure for the remaining batches of chemical surrogate.

29. **RINSE** and **FLUSH** the chemical debris storage tanks and lines to ensure that 100% of the chemical debris has been introduced into the test tank.

30. **MAINTAIN** the recirculation flow rate and MONITOR the head loss across the test strainer for at least 15 test tank turnovers after rinsing and flushing the chemical debris storage tanks and lines.

31. **RUN** the test until the change in head loss is less than 1% in 30 minutes unless directed otherwise by the Test Engineer. The Test Engineer has the discretion to continue the test, if experimental observation necessitates.

32. After the termination criteria is met, **REDUCE** the flow to 50% of the design flow rate to observe if bore holes may have formed.

33. **MAINTAIN** the recirculation flow rate and MONITOR the head loss across the test strainer for at least one (1) test tank turnover.

34. **OBSERVE** the effects of the reduced flow rate on the measured head loss, RECORD head loss observations.

35. **MAINTAIN** the recirculation flow rate and OBSERVE the area above the strainer for vortexing.

36. **TERMINATE** the test once all observations of the head loss are deemed acceptable unless directed otherwise by the Test Engineer.

Note: The head loss should decrease approximately four times since the head loss is proportional to the velocity squared. If the head loss fluctuates and does not stabilize, bore holes may have formed through the debris bed.

Attachment 2 to Enclosure 3

General Debris Preparation Criteria

The following steps present a general approach for preparing debris prior to introduction into the test tank. Common debris sizes include fines, smalls, and larges. As stated in the general test protocol, debris is introduced, starting with the most transportable (fines) to least transportable (larges). Debris types will be individual debris types and will not be mixed to for a homogeneous mixture (i.e., dirt and dust particulate will not be mixed with coating particulate). The purpose of these steps is to prevent agglomeration of the non-chemical debris. It is ESSENTIAL that the debris is diluted such that agglomeration/clumping of the debris do not occur.

1. **PREPARE** the debris according to the following steps unless otherwise indicated by the Test Engineer.

   Note: The non-chemical debris has been prepared by Performance Consulting, Inc. (PCI) in accordance with PCI Technical Document No. SFSS-TD-2007-004; Sure-Flow® Suction Strainer - Testing Debris Preparation and Surrogates and shipped to Alden Research Laboratory. Changes to this document implemented in the test plan or test(s) shall be documented in the Test Plan with justification, as applicable.

2. **WEIGH** the non-chemical debris dry in accordance with the quantities specified in the debris allocation tables.

3. **ALLOCATE** debris into equal amounts into multiple 5-gallon buckets filling each bucket with no more than 1/6 full of debris. This procedure applies to all fiber and particulate debris.

4. **COMBINE** each batch of the non-chemical debris with water and store for introduction into the test tank in mixing containers. The debris may be "mixed" with hot water (~120 °F) to help remove trapped air from fibrous debris. Use the following steps to mix the debris:

   a. **DILUTE** the debris with hot water (~120 °F) to an approximate ratio of 5 parts water to 1 part debris (by volume).

   b. **MIX** the debris and heated city water in mixing containers.

   c. If needed, **FURTHER** dilute the debris to ensure there is no agglomeration.

Attachment 3

Additional Test Tanking Inputs

1. Approach Velocity

USNRC Position: *Justify that the weighted average approach velocity calculation is conservative.*

Approach: The test tank protocol does not rely on the weighted average approach velocity to simulate plant approach velocities. The test tank has been designed to keep debris suspended and does not credit near field debris settling.

2. Flume Turbulence

USNRC Position: *Justify the test flume turbulence levels are bounding of plant containment turbulence levels.*

Approach: The test tank protocol does not rely on the weighted average approach velocity to simulate plant approach velocities. The test tank turbulence is not intended to simulate the containment turbulence, and has been designed to ensure sufficient turbulence to keep debris in suspension in the test tank using a perforated floor and mechanical mixing.

3. Alternate Break Location to Bound Approach Velocity

USNRC Position: *Justify that the break associated with the maximum debris load is more conservative than an alternate break location in terms of debris transport characteristics and bounding flume velocities.*

Approach: Use of the test tank protocol does not require evaluation of the approach velocities for each break location. Therefore, the maximum debris load will result in the largest debris load being used in the strainer testing.

4. Effects of Sources of Water Draining into Recirculation Pool From Above

USNRC Position: *Demonstrate that there are no sources of water falling from above that could introduce additional turbulence in the approach flow stream used to define the test flume configuration or show that they are conservatively represented in the test flume configuration/operation.*

Approach: The turbulence associated with falling water is irrelevant for test tank strainer testing. The test tank does not simulate the strainer approach velocities or turbulence, and is designed to keep the debris suspended for the duration of the test.

Attachment 3

Additional Test Tanking Inputs

5. Fiber Erosion in Test Flume

USNRC Position: *Debris introduced as transportable in the test flume and found to settle would erode over the mission time of the post-Loss of Coolant Accident response. Therefore some accounting of the erosion of flume settled debris must be made.*

Approach: The test tank protocol will preclude debris settling within the test tank. Turbulence in the test tank will maintain debris suspension for transport to the strainer.

6. Debris Concentration on Introduction

USNRC Position: *The concentration of debris upon introduction is important to eliminate nonprototypical agglomeration in the introduction vessel.*

Approach: The debris will be mixed with water with a minimum dilution of 5 parts water to 1 part debris constituent. The debris will be introduced to the test tank via a trash pump and discharge pipe to ensure the debris is mixed as it enters the tank. The discharge pipe will be below the surface of the test tank water to ensure air is not entrained in the debris mixture as it enters the tank.

The debris dilution rates will follow March 2008 guidance conservatively. Debris introduction will be documented in the report along with photos and/or videos taken during the test to validate no significant agglomeration of debris occurred prior to introduction.

7. Description of ALDEN's use of Alion's Computational Fluid Dynamics (CFD) Results to Define Flume Walls

USNRC Position: There is no NRC position for this item.

Approach: CFD results are not used and, thus, are not applicable for the test tank protocol.

Enclosure 4

List of Regulatory Commitments

1. Unit 2 will install sump modifications per the requirements of Generic Letter (GL) 2004-02 prior to Unit 2 fuel load. (Response to ***Item 1.*** of Enclosure 1.)

2. A confirmatory walkdown for loose debris will be performed on Unit 2 after containment work is completed and the containment has been cleaned. This walkdown will be completed prior to startup. (Response to ***Items 1.***, ***3.d.1.***, ***3.d.3*** of Enclosure 1; ***Open Item 3*** of Enclosure 2.)

3. New throttle valves will be installed in the CVCS and SI injection lines to the RCS. The new valves will be opened sufficiently to preclude downstream blockage.

   (Response to ***Item 2.*** of Enclosure 1.)

4. The current Unit 1 TVA protective coating program contains requirements for conducting periodic visual examinations of Coating Service Level I and Level II protective coatings. The Unit 2 program will be the same.

   (Response to ***Item 3.h.7.*** of Enclosure 1)

5. Procedural controls will be put in place at WBN Unit 2 to ensure that potential quantities of post-accident debris are maintained within the bounds of the analyses and design bases that support ECCS and CSS recirculation functions.

   (Response to ***Item 3.i.*** of Enclosure 1)

6. TVA will complete the WBN in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 following issuance of the final NRC Safety Evaluation Report (SER) for Topical Report No. WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid."

   (Response to ***Item 3.n.1.*** of Enclosure 1 and ***RAI 9.*** of Enclosure 3)

7. The design basis of the modified emergency sump strainer has been incorporated into the plant's current licensing basis. The WBN Unit 2 FSAR will be amended to include this information.

   (Response to ***Item 3.p.*** of Enclosure 1)