Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

September 10, 2010

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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 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors**

The purpose of this letter is to provide information to support U.S. Nuclear Regulatory Commission (NRC) verification that the corrective actions to address Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for WBN Unit 2 are adequate. This response was prepared using the guidelines set forth in Reference 1.

Enclosure 1 provides the necessary supplemental responses addressing Generic Letter actions at WBN Unit 2 using the guidelines set forth in Reference 1 and the Watts Bar Unit 1 responses in Reference 2. Enclosure 2 addresses the 11 remaining open items that are applicable to WBN Unit 2 from the NRC audit of the WBN GL 2004-02 resolution described in Reference 3. Enclosure 3 is the WBN Unit 1 Request for Additional Information Supplemental Response to GL 2004-02 (References 4 and 5), with applicable Unit 2 information included.

Enclosure 4 identifies those actions committed to by TVA 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 10th day of September 2010.

Sincerely,

M. Bajestani

Masoud Bajestani
Watts Bar Unit 2 Vice President

A116
NRR

References:

1. NRC letter to Nuclear Energy Institute (NEI), "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007

2. TVA Letter to NRC, "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)," dated March 31, 2008

3. TVA letter to NRC, "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)," dated July 3, 2006

4. TVA Letter to NRC, "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)," dated March 3, 2009

5. TVA Letter to NRC, "Draft Responses to Requests for Additional Information Related to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated June 3, 2010

Enclosures:

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

2. NRC Audit Open Items

3. WBN Unit 1 RAI Supplemental Response to GL 2004-02 Updated to Include WBN Unit 2

4. List of Regulatory Commitments

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 WBN Unit 2 Using Revised Content Guide for GL 2004-02 Supplemental Responses

This Enclosure provides the necessary supplemental response addressing Generic Letter (GL) 2004-02 actions at Watts Bar Nuclear Plant (WBN) Unit 2, using the guidelines set forth in the NRC letter to Nuclear Energy Institute (NEI) dated November 21, 2007, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses."

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. Unit 2 will install sump modifications per the requirements of the Generic Letter, which are bounded by the modifications performed for Unit 1. The NRC performed an audit of the WBN Unit 1 sump evaluations and issued a final report by letter entitled "Watts Bar Nuclear Plant, Unit 1 – Audit Report of New Strainer Design in Response to GL 2004-02 and Generic Safety Issue -191" dated February 7, 2007. The letter concluded that "overall the staff's impression is that the WBN new sump modifications appear to be robust with sufficient design margin." The report did have open Unit 1 actions for resolution which are provided at the end of this supplementary response. These will also be resolved for Unit 2 by fuel load.

The Unit 2 containment is a mirror image of design to the Unit 1 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. 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 WBN 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. These walkdowns will apply to WBN Unit 2. The containments are the same.

Reflective metallic insulation will be used on Unit 2 as on Unit 1. Unit 2 contains the original model D3 steam generators which were present in Unit 1 at the time of the walkdowns. The coatings systems are the same between Unit 1 and Unit 2.

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 debris generation will be the same in Unit 2 as in Unit 1 with the exception that the Unit 2 containment does not contain min-K (microtherm) insulation and does not contain 3M fire-wrap. These fibrous materials will not be present in Unit 2.

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 the SER in Appendices III, IV, and VI. 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, the pump capacities and flow rates are the same and, therefore, the Unit 1 transport analysis will apply 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 and safety injection system lines to the RCS loops post accident whereas Unit 2 will use specially design throttle valves. The valves will require separate evaluation for post accident recirculation fluid erosion. This will be completed by December 20, 2010.

Chemical Effects Evaluation
A comparison of the NRC industry integrated chemical effects test program Test 5 and the WBN plant-specific parameters have been performed. The evaluation concluded that the critical parameters in the integrated chemical effects test program Test 5 are similar to 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 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 4600 ft^2. Additional strainer head loss tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design.

WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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

The containment sump intake structures will be modified to include advanced designed strainers prior to fuel load (EDCR 53580). The design is the same as Unit 1 with the exception of one design enhancement on plenum opening diameter below the strainers. Unit 2 uses a larger opening to below the strainer to reduce the pressure drop entering the plenum. Additionally, new throttle valves have been procured for installation in the CVCS and SI injection lines to the RCS loops as described above. The new throttle valves will be installed under EDCR 54783. All work will be completed consistent with the systems completion and testing schedules. Since WBN Unit 2 is not an operating plant, the strainer and associated changes must be completed prior to fuel load. Additional tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and perform additional testing if necessary. Further, several calculations will be revised. The NPSH calculations will be revised to address the results of strainer head loss testing and clean strainer head loss (CSHL) computational fluid dynamics (CFD) updates. Calculation revisions for minimum sump water level that are expected to confirm that strainer submergence will be demonstrated for all operating conditions.

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 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.3. 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 above 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 reactor coolant system (RCS) loops near each of the steam generators (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 zone of influence (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

At WBN, the emergency core cooling 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 insulation types in lower containment, 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 steam generator 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. With the exception of a small quantity of mineral wool in penetrations where it would not be destroyed, WBN Unit 2 does not have large amounts of fibrous material inside containment. Each of the break cases examined includes the analysis of potential fiber release. Additional strainer head loss tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

Debris generation calculations will be revised for a break in the 31" inner diameter crossover leg at the base of the steam generator for each of the primary system loops. The design basis debris loading supported by strainer head loss testing will bound the worst case RMI debris load with the worst case fiber and particulate load.

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 Safety Evaluation Report (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 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 steam generator 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 lb	0 lb	85 lb
Phenolic Paint	137 lb	0 lb	137 lb
IOZ Paint	1,152 lb	0 lb	1,152 lb
Alkyd Paint	44 lb	0 lb	44 lb
Epoxy Paint	25 lb	0 lb	25 lb
Carboline 295	752 lb	0 lb	752 lb
Silicone Paint	42 lb	0 lb	42 lb

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 lb	0 lb	85 lb
Phenolic Paint	137 lb	0 lb	137 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	753 lb	0 lb	753 lb
Silicone Paint	49 lb	0 lb	49 lb

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 lb	0 lb	85 lb
Phenolic Paint	149 lb	0 lb	149 lb
IOZ Paint	1,147 lb	0 lb	1,147 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	48 lb	0 lb	48 lb

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 lb	0 lb	85 lb
Phenolic Paint	146 lb	0 lb	146 lb
IOZ Paint	1,148 lb	0 lb	1,148 lb
Alkyd Paint	44 lb	0 lb	44 lb
Epoxy Paint	25 lb	0 lb	25 lb
Carboline 295	817 lb	0 lb	817 lb
Silicone Paint	40 lb	0 lb	40 lb

The latent debris and dirt/dust values in the above tables have been reduced by 50% from the original ALION analysis. The ALION calculation will be updated accordingly. The new values were established to remain below the walkdown results from Unit 1.

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 1000 ft^2 was used for tapes, tags, labels, etc inside the containment. Based on containment walkdown results documented in WAT-D-11530 for Unit 1, 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. Signage for U2 will be similar.

The entire quantity of signs, placards, tags, tape and similar miscellaneous materials were 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 percent 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 percent of the affected RMI was destroyed in 1/4-inch to 2-inch pieces and 29 percent 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 percent small pieces and 25 percent 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). All steel 6 feet from 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. All concrete below 6 feet has been painted with a Carboline™ 295 surfacer and then painted with two coats of Phenoline™ 305. The original steam generators 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. All 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 lb/ft^3. However, the dry film bulk density of Carbozinc™11 is only 223 lb/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 lb/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 lb/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 lb/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 lb/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 lb/ft^3. A dry film bulk density of 87 lb/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 lb/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 lb/ft^3, and the material (individual fiber) density of latent fiber was assumed to be 94 lb/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 lb/ft^3	105 lb/ft^3
IOZ Paint (Fines)	223 lb/ft^3	457 lb/ft^3
Alkyd Paint (Fines)	98 lb/ft^3	98 lb/ft^3
Carboline 4674 (Fines)	87 lb/ft^3	145 lb/ft^3
Carboline 295 (Fines)	123 lb/ft^3	123 lb/ft^3
Epoxy (Fines)	94 lb/ft^3	94 lb/ft^3
Dirt/Dust (Fines)	-	169 lb/ft^3
Latent Fiber (Fines)	2.4 lb/ft^3	94 lb/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 Item 3.d.2 below. A quantitative latent debris walkdown was performed on WBN U1 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 preset 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 will be performed on Unit 2 after containment work is completed and the containment has been cleaned and walkdown for loose debris. This will be done prior to startup. This is tracked under Westinghouse task WBS 5.3 Rev. 1.

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 percent of the mass of the total latent debris inventory with particulate contributing the remaining 85 percent.
- Latent fiber material has an average density of 94 lb/ft^3
- Latent particulate material has a nominal density of 169 lb/ft^3
- Latent fiber material has an as-manufactured density (dry bed bulk density) of 2.4 lb/ft^3
- 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 lb. This value was reduced by 50% to be more representative of the containment conditions yet still bound the Unit 1 walkdown results. The 100 lb result is used for Unit 2. Of the 100 lbs, 85 lb was assumed to be dirt/dust and the remaining 15 lb was 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 Unit1 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 lb. The latent debris survey results confirmed that the assumptions described in Item 3.d.2 above are conservative with respect to both composition and quantity of the actual latent debris in the WBN containment buildings. A similar walkdown will be performed on U2 as described in 3.d.1 above.

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 above, 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 emergency core coolant system (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.

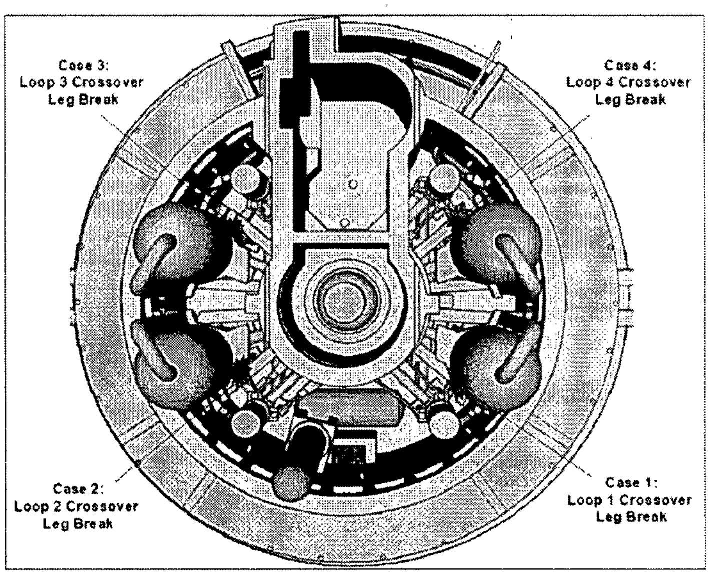
9) A graphical determination of the transport fraction of each type of debris was made using the velocity and turbulent kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.

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 WBN Unit 1. WBN 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 deviate from the approved guidance documents discussed in Item 3.e.1 above.

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 3-D 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-3-D 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 above.

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 steam generator 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 determined from the CFD simulations performed for a break in the 31" inner diameter crossover leg at the base of the steam generator 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 changes 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 lb	1.0	149 lb
IOZ	1,161 lb	1.0	1,161 lb
Alkyds	44 lb	1.0	44 lb
Epoxy Paint	25 lb	1.0	25 lb
Carboline 295	836 lb	1.0	836 lb
Silicone	49 lb	1.0	49 lb
Latent Debris			
Latent Fiber(3)	6.25 ft^3	1.0	6.25 ft^3
Dust & Dirt	85 lb	1.0	85 lb
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 lb/ft^3). This gives a latent fiber volume of 6.25 ft^3 (15 lb/2.4 lb/ft^3).
(4) Section 3.5.2.2.2 of the SER for NEI-04-07 allows a 75 percent 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 percent 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.

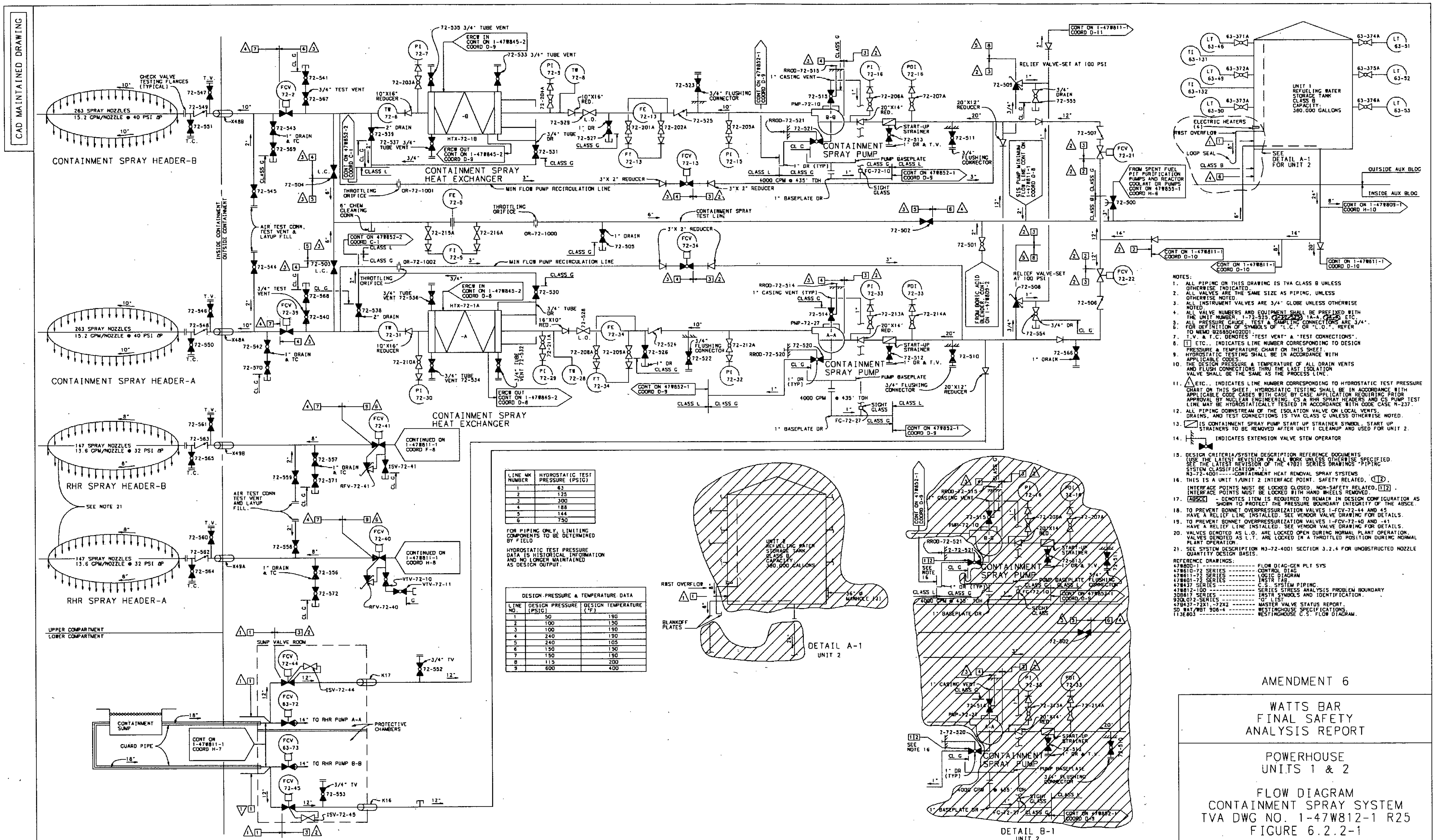
3.f. Head Loss and Vortexing

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

Schematic flow diagrams of the WBN ECCS and CSS are contained in the WBN Unit 1 Final Safety Analysis Report (FSAR). Refer to Figure 6.2.2-1 for the CSS and Figure 6.3-1-1 for the ECCS. (Copies are provided below 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

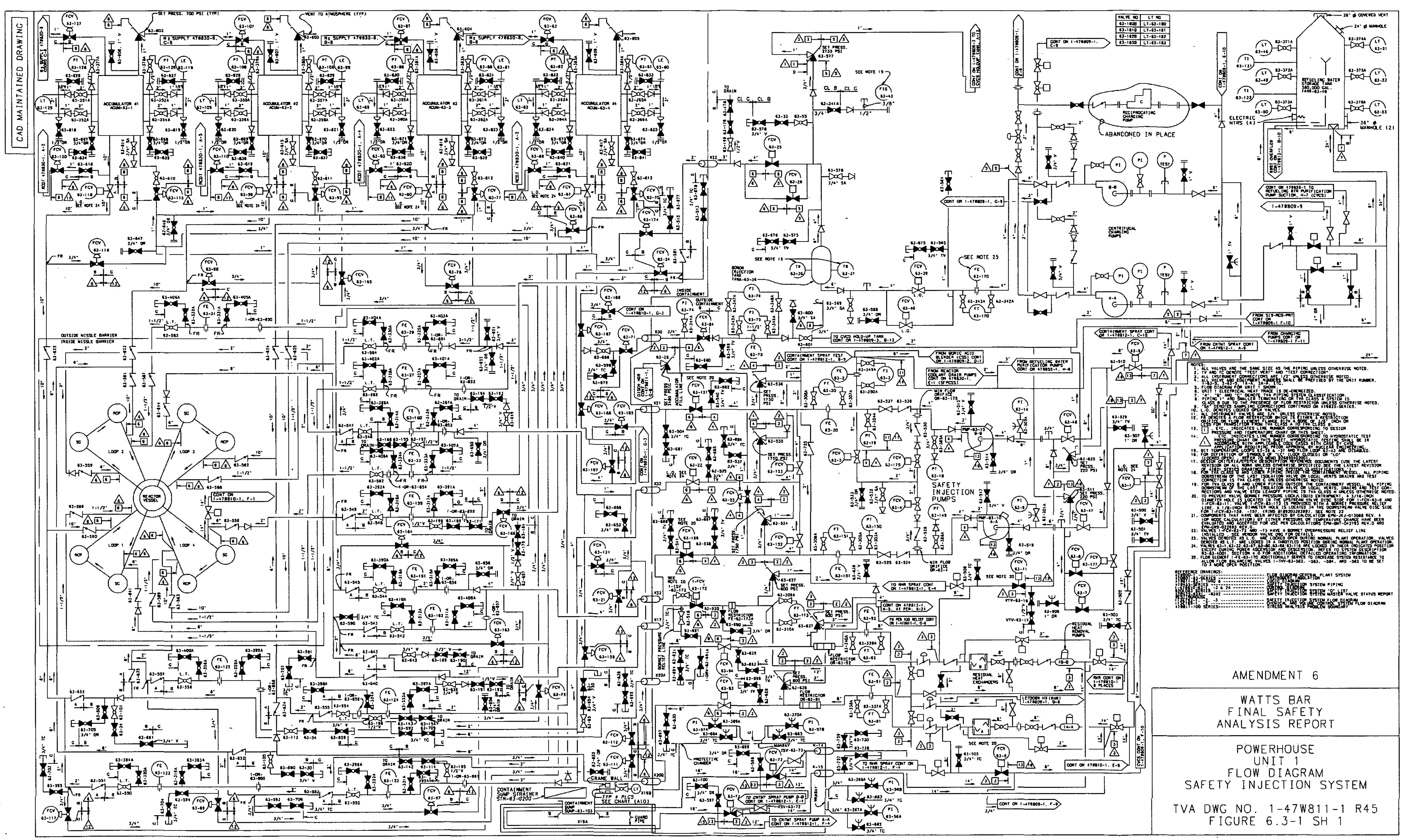
LINE NO.	DESIGN PRESSURE (PSIG)	DESIGN TEMPERATURE (°F)
1	50	190
2	100	150
3	100	190
4	240	190
5	240	105
6	150	150
7	150	190
8	115	200
9	600	400

NOTES:

1. ALL PIPING ON THIS DRAWING IS TVA CLASS B UNLESS OTHERWISE INDICATED.
2. ALL VALVES ARE THE SAME SIZE AS PIPING, UNLESS OTHERWISE NOTED.
3. ALL INSTRUMENT VALVES ARE 3/4" GLOBE UNLESS OTHERWISE NOTED.
4. ALL VALVE NUMBERS AND EQUIPMENT SHALL BE PREFIXED WITH THE UNIT NUMBER, 1-72-525, (2-72-525) 1A-A, (2A-A) ETC.
5. ALL PRESSURE GAUGE, TEST & SAMPLING CONNECTIONS ARE 3/4".
6. FOR DEFINITION OF SYMBOLS OF "L.C." OR "L.O.", REFER TO MEMO B26850402001.
7. T.V. & T.C. DENOTES "TEST VENT" & "TEST CONNECTIONS".
8. [1] ETC., INDICATES LINE NUMBER CORRESPONDING TO DESIGN PRESSURE & TEMPERATURE CHART ON THIS SHEET.
9. HYDROSTATIC TESTING SHALL BE IN ACCORDANCE WITH APPLICABLE CODES.
10. THE DESIGN PRESSURE & TEMPERATURE OF ALL DRAIN VENTS AND FLUSH CONNECTIONS THRU THE LAST ISOLATION VALVE SHALL BE THE SAME AS THE PROCESS LINE.
11. △1 ETC., INDICATES LINE NUMBER CORRESPONDING TO HYDROSTATIC TEST PRESSURE CHART ON THIS SHEET. HYDROSTATIC TESTING SHALL BE IN ACCORDANCE WITH APPLICABLE CODE CASES WITH CASE BY CASE APPLICATION REQUIRING PRIOR APPROVAL BY NUCLEAR ENGINEERING. CS & RHR SPRAY HEADERS AND CS PUMP TEST LINE MAY BE HYDROSTATICALLY TESTED IN ACCORDANCE WITH CODE CASE N-237.
12. ALL PIPING DOWNSTREAM OF THE ISOLATION VALVE ON LOCAL VENTS, DRAINS, AND TEST CONNECTIONS IS TVA CLASS G UNLESS OTHERWISE NOTED.
13. [/] IS CONTAINMENT SPRAY PUMP START UP STRAINER SYMBOL. START UP STRAINERS TO BE REMOVED AFTER UNIT 1 CLEANUP AND USED FOR UNIT 2.
14. INDICATES EXTENSION VALVE STEM OPERATOR
15. DESIGN CRITERIA/SYSTEM DESCRIPTION REFERENCE DOCUMENTS (USE THE LATEST REVISION ON ALL WORK UNLESS OTHERWISE SPECIFIED. SEE THE LATEST REVISION OF THE 47B21 SERIES DRAWINGS "PIPING SYSTEM CLASSIFICATION."):
    N3-72-4001-----CONTAINMENT HEAT REMOVAL SPRAY SYSTEMS
16. THIS IS A UNIT 1/UNIT 2 INTERFACE POINT. SAFETY RELATED, (1|2). INTERFACE POINTS MUST BE LOCKED CLOSED. NON-SAFETY RELATED, [1|2]. INTERFACE POINTS MUST BE LOCKED WITH HAND WHEELS REMOVED.
17. [ABSCE] - DENOTES ITEM IS REQUIRED TO REMAIN IN DESIGN CONFIGURATION AS SHOWN TO PROTECT THE PRESSURE BOUNDARY INTEGRITY OF THE ABSCE.
18. TO PREVENT BONNET OVERPRESSURIZATION VALVES 1-FCV-72-44 AND 45 HAVE A RELIEF LINE INSTALLED. SEE VENDOR VALVE DRAWING FOR DETAILS.
19. TO PREVENT BONNET OVERPRESSURIZATION VALVES 1-FCV-72-40 AND -41 HAVE A RELIEF LINE INSTALLED. SEE VENDOR VALVE DRAWING FOR DETAILS.
20. VALVES DENOTED AS L.O. ARE LOCKED OPEN DURING NORMAL PLANT OPERATION. VALVES DENOTED AS L.T. ARE LOCKED IN A THROTTLED POSITION DURING NORMAL PLANT OPERATION.
21. SEE SYSTEM DESCRIPTION N3-72-4001 SECTION 3.2.4 FOR UNOBSTRUCTED NOZZLE QUANTITY DESIGN BASIS.

REFERENCE DRAWINGS:

47W800-1 ---------------- FLOW DIAG-GEN PLT SYS
47W610-72 SERIES -------- CONTROL DIAG
47W611-72 SERIES -------- LOGIC DIAGRAM
47W601-72 SERIES -------- INSTR TAB.
47W437 SERIES ----------- C.S. SYSTEM PIPING.
47W812-100 -------------- SERIES STRESS ANALYSIS PROBLEM BOUNDARY
30B617 SERIES ----------- INSTR SYMBOLS AND IDENTIFICATION.
92QL072-SERIES ---------- "Q" LIST
47B437-72X1,-72X2 ------- MASTER VALVE STATUS REPORT.
SD WAT/WBT 906-4 -------- WESTINGHOUSE SPECIFICATIONS.
113E803 ----------------- WESTINGHOUSE C.S. FLOW DIAGRAM.


CAD MAINTAINED DRAWING
REACTOR VESSEL
SAFETY INJECTION PUMPS
ABANDONED IN PLACE
AMENDMENT 6
WATTS BAR
FINAL SAFETY
ANALYSIS REPORT
POWERHOUSE
UNIT 1
FLOW DIAGRAM
SAFETY INJECTION SYSTEM
TVA DWG NO. 1-47W811-1 R45
FIGURE 6.3-1 SH 1

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. Calculation revisions for minimum sump water level are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.

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 WBN UFSAR Figure 6.3-6 were altered by the modification, the effect of the change was qualitatively determined to be neutral or 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. All of the WBN strainer module disks are nominally 5/8" thick with a 1" separation between adjacent disks. The interior of the disks contain rectangular wire stiffeners for support. They 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 vortex formation 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.

Even for a very small SBLOCA, the short WBN sump strainers are submerged at the initiation of sump recirculation operation and the tall strainers are only slightly uncovered. Thus, vortex formation in the sump would not be expected to occur for SBLOCA recirculation operation.

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

Original testing of the advanced design containment sump suction strainers for WBN Unit 1 was conducted at Alden Research Laboratory in Holden, Massachusetts to confirm strainer performance and design margins for various service conditions. The testing was performed to assess the effects of debris loading on strainer performance based on the final strainer configuration for WBN (i.e., the strainer surface area and maximum strainer opening size) and the existing plant emergency core cooling system (ECCS) flow requirements.

The original tests were conducted in a flume with approximate dimensions of 27" wide x 39" high x 20'-9" long. The test apparatus included the test flume, a recirculation pump, the test strainer module, instrumentation and controls and associated piping to operate the pump in a recirculation mode. The recirculation flow rate used in the testing was based on the scaled WBN design basis ECCS volumetric flow rate. The debris quantity for the strainer test was in proportion to the scaled flow through the test module. new test

The following debris loading conditions were included in the original strainer test program.

Test 1 – Design Basis Test

This test measured the performance of the containment sump strainers for the design basis debris load case established by the WBN plant specific debris transport study. The size of the failed coatings in this test was 10 μm particles to match the assumption of the design basis transport analysis. This assumption was intended to maximize the amount of failed coatings which could transport to the sump screen for potential formation of a fiber thin bed. The results of the transport study confirmed that a thin bed would not form based on WBN plant specific sump recirculation flow and debris characteristics. This test matched the design basis conditions and established the design basis performance for the strainers.

Test 2 – Limiting Coating Size Test

This test measured the performance of the containment sump strainers for the design basis debris load case established by the WBN plant specific debris transport study with a modified failed coating size. The debris load is the same as for the design basis test with one exception. While the size of the failed coatings modeled in the design basis maximizes the debris transport, the size does not result in maximum strainer blockage given that the analyzed conditions are such that "thin bed' fiber blockage will not occur. To maximize the failed coating blockage effect, the size of the failed coatings in this test were paint chips which were all larger than the sump strainer openings (i.e., approximately 1/8" square and 5 mils thick). While there will be more settling of the larger size chips before they reach the strainers, the same transport fraction for the 10 μm particles was conservatively applied to the chips. This test established the design basis performance for the strainers for the worst case failed coating size (i.e., larger than the 0.085" maximum strainer opening size).

Test 3 – Maximum Coating Inventory Test

This test measured the performance of the containment sump strainers for a maximum coating debris load case. The debris load is the same as for the design basis test with the following exceptions. The failed coating quantities for phenolic and inorganic zinc coatings (IOZ) have been increased to reflect the total amount of qualified and unqualified coatings inside containment. The quantities of these coatings were conservatively established by increasing the design basis quantities approximately an order of magnitude. The size of the failed coatings was revised to reflect a spectrum of chip sizes which are reflective of the actual coating failure mode with the exception of the IOZ coatings. Based on industry testing, the IOZ coatings will fail as particulate. As the revised coating sizes will be equal to or greater than the size modeled in the debris transport study, they will conservatively maximize the potential strainer blockage assuming the same transport fraction. Additionally, debris to address potential containment sump chemical effects was also added. The chemical information is based on Test No. 5 of the Integrated Chemical Effects Test (ICET) project conducted by industry groups. The results from Test No. 5 are intended to be applicable to ice condenser containment materials. This test established strainer performance for beyond design basis quantities of failed coatings and established the strainer design margin for failed coating debris. It was intended to demonstrate operational margins needed to address potential containment qualified coating issues beyond the established design basis as well as potential strainer blockage due to chemical effects.

Test 4 – Test 4 was bounded by Test 3; therefore test 4 was not performed.

Two informal tests were conducted following Test 2 and Test 3 to gain insight on the "near field" effects and the effects of fibrous debris on strainer head loss.

Informal Test following Test 2

Following test 2 additional fiber was poured into the flume within 1 foot of the strainer. At a flow rate of 68 gpm, the head loss was observed to be 0.101 ft and at 129 gpm, the head loss was observed to be 0.27 ft.

Informal Test following Test 3

Following test 3, the mixed debris was manually pushed towards the strainer (the mixed debris, consisting mostly of paint chips, formed a mound over the strainer and completely covered the strainer). At a flow rate of 68 gpm, the head loss was observed to be 0.03 ft, at 120 gpm, the head loss was 0.2 ft.

The specific measured head loss experienced during each test is summarized below.

Summary of As-Tested Strainer Head Loss with Debris Loaded Flume

Test Number	Clean Strainer Head Loss (ft)	Measured Head Loss (ft)	Velocity Head Loss (ft)	Debris Load Head Loss (ft)	Average Water Temperature (°F)
1	0	0.022	0.0111	0.011	49.5
2	0	0.027	0.0109	0.016	51.5
3	0	0.060	0.0109	0.049	51.3

(1) Test 4 was bounded by Test 3, therefore test 4 was not performed.
(2) There was insufficient fiber collection at the strainer during the tests to form a dense thin bed.

Additional tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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

<u>TVA Response</u>

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 above. Impact of subsequent testing will be evaluated as described above.

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

<u>TVA Response</u>

The WBN advanced design containment sump strainers have been designed to preclude the formation of a fiber bed (thin or thick) for post accident sump recirculation operation. Based on containment building walkdowns performed for WBN 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.

WBN Unit 2 plant conditions are such that a thin bed 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 thin bed formation. The final sump strainer flow area (4600 ft^2) was selected such that thin bed effect head losses are not expected to occur.

To confirm this design objective, a series of flow transport/blockage tests were performed. The design basis test case was performed with all failed coatings simulated as 10 μm particles. This test was intended to maximize small particulate transport to the sump screen and serve as a limiting case for thin bed blockage effects. Upon confirmation that the strainer design will preclude thin bed formation, additional tests were performed to evaluate other sump blockage mechanisms. These tests included 1) the limiting failed coating size for maximum strainer blockage (i.e., the size of the failed coatings in this case were approximately 1/8" square and 5 mils thick and were considered small enough to maximize transport and large enough to maximize strainer blockage); and 2) the maximum coating inventory (i.e., the coating quantities for phenolic and inorganic zinc coatings were increased to reflect the total amount of qualified and unqualified coatings inside containment). In all cases, thin bed formation did not occur.

Additional tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These test further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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. Strainer head loss values established from prototype test data were increased by 6 percent to bound test measurement uncertainties.

b. Strainer flow plenum head loss values calculated using standard hydraulic flow resistance equations were conservatively increased by 10 percent.
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 Test 3 in the response to Item 3.f.4 above). This determination may be impacted by the evaluation of subsequent testing conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These test further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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 percent was then applied to this result to bound any measurement error associated with the prototype testing equipment. This value is recorded as the "Test Uncertainty Correction" in the table below. Key features of the prototype test assembly were then reviewed relative 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 percent 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 percent 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	U2
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 WBN U2 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 WBN 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 above to the limiting clean strainer head loss value established as described in the response to Item 3.f.9 above. 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 below.

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 WBN Unit 1 testing are as follows.

WBN Debris Laden Containment Sump Strainer Head Loss Summary

Head Loss Parameter	WBN U2
Clean Strainer Head Loss	0.338 ft
Strainer Debris Laden Head Loss (Tested) with Temperature Correction for Post-LOCA Temperatures Applied	0.031 ft
Total Strainer Head Loss	**0.369 ft**

Based on these results, a limiting debris laden head loss value of 0.360 ft was established for the WBN Unit 2 strainer assemblies. However, these results may be impacted by subsequent testing on WBN Unit 1 and SQN. These results will be updated by December 20, 2010.

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

Calculation revisions for minimum sump water level are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.

As discussed in the response to Item 3.f.3, sump vortexing and significant air intrusion do not occur for this operating configuration.

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. As discussed in response to Item 3.f.4, two informal tests were performed to establish that potential "near field flow effects" associated with the testing configuration do not a have a significant effect on the measured strainer head loss.

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 percent 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.

WBN ECCS and CSS Flows Rates for Sump Recirculation NPSH Calculation

	Large Break LOCA	Small Break LOCA
CSS	4600 gpm	4600 gpm
ECCS (Residual Heat Removal)	5000 gpm	5000 gpm
Total Recirculation Flow	**9600 gpm**	**9600 gpm**

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

Calculation revisions for minimum sump water level are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.

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 above. 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 5000 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 SIPs and CCPs (approx 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 (4600 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 below.

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 percent 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 5 & 6)

In response to a LOCA, the residual heat removal (RHR) centrifugal charging (CCP), and safety injection (SIP) pumps automatically start upon receipt of a safety injection signal. These pumps initially inject borated water from the refueling water storage tank to the primary system cold legs. This mode of operation is referred to as the ECCS injection mode of operation. The containment spray system (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 WBN U1 this is approximately 3 hours after the event due to the higher boron requirements for the tritium producing burnable absorber rod program. (Although the U2 license will not include tritium production, the boron values have been kept the same to reduce potential for errors between units and 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 and a small break LOCA are as follows.

- 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 a small break LOCA scenario, the containment accident pressure may remain below the actuation setpoint for CSS.
- In the small break LOCA 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 small break LOCA 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., large break LOCA and small break LOCA) 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 is 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 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.

Discharge volumes which are 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, in the long term, excess water spills from inside the crane wall through unsealed penetrations into the raceway where it is unavailable for future recirculation.

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 a Large Break LOCA

(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 are 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. 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 is 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 Small Break LOCA

(1) The small break LOCA must be evaluated for two possible scenarios regarding minimum containment sump elevations. These scenarios are 1) a very small break assumed at 120 gpm to be slightly above the definition of a LOCA and 2) a more typical small break LOCA of 2000 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. That size break would 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, vapor content 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 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, steam generator 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 steam generators do not have the curb over approx 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 large break LOCA, 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 small break LOCA, only the leakage flow until switchover is considered for the primary system inventory.

2) Cold Leg Accumulator Inventory – For a large break LOCA, 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 small break LOCA, no credit is taken for the volume of the accumulators.

3) RWST Inventory – For both the large and small break LOCA, 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 large break LOCA, 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 small break LOCA, 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:

WBN Sump Recirculation Pool Source Inventory Summary (RHR switchover)

	Large Break LOCA	**Small Break LOCA***
Primary System Inventory	50,500 gallons	42,810 gallons
Cold Leg Accumulator Inventory	22,900 gallons	0 gallons
RWST Inventory	202,000 gallons	202,000 gallons
Ice Melt Inventory	147,240 gallons	50,752 gallons
Total	**422,640 gallons**	**295,561 gallons**

*2000 gpm SBLOCA case shown, 120gpm SBLOCA also analyzed for strainer performance with slightly more limiting water level results.

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	8.7 ft
CS system	5.5 ft

The NPSH calculations will be revised to include the results of strainer head loss testing, and CSHL CFD updates, address calculation revisions for minimum sump water level that are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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 previously, essentially all steel surfaces at WBN are coated with Carbozinc™ 11 (an inorganic zinc primer). All steel 6 feet from 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. All concrete below 6 feet has been painted with a Carboline™ 295 surfacer and then painted with two coats of Phenoline™ 305. The original steam generators 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. All 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 follows.

General Assumptions

1) It was assumed that ¼"-4" pieces of RMI debris can be conservatively treated as ½" pieces and 4"-6" pieces can be conservatively treated as 2" 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 when 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 WBN Unit 1 original containment sump strainer test program is described in the response to Item 3.f.3 above. The various debris loads used in the strainer testing established the ability of the sump strainer design to accommodate coating debris equal to the total amount of qualified and unqualified coatings inside containment. 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.

- <u>Silicon Carbide</u> – This material was substituted for phenolic, alkyd and silicone coatings where the coatings were assumed to fail as particulates.
- <u>Amerlock 400 NT</u> – This material was substituted for phenolic, alkyd and silicone coatings where the coatings were assumed to fail as chips.
- <u>Tin Particles</u> – 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.

<u>TVA Response</u>

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

- <u>Silicon Carbide</u> – 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.

As described above, additional sump tests have been conducted for WBN Unit 1 and SQN which have not yet been correlated to the Unit 2 debris loading. This evaluation and any changes required by that evaluation will be performed by December 20, 2010.

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 will also apply 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 diameter ratio (r/D) of 10.0.
4) The quantity of coating debris generated was determined based on 1) all coatings (qualified or unqualified) in the pipe break ZOI will fail, 2) all qualified coatings outside of the ZOI will remain intact and 3) all unqualified coatings outside of the ZOI will fail.
5) All 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 the 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 above. 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 U2 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.

The 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" – A procedure that 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" – A procedure that 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" – This maintenance and modification process 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" – This procedure 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" – This procedure 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" – This instruction 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" – This procedure 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" – This engineering specification provides the technical and programmatic requirements for the protective coating programs at TVA nuclear plants.

10) Modification/Addition Instruction MAI-5.3, "Protective Coatings" – This procedure 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" - This procedure 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

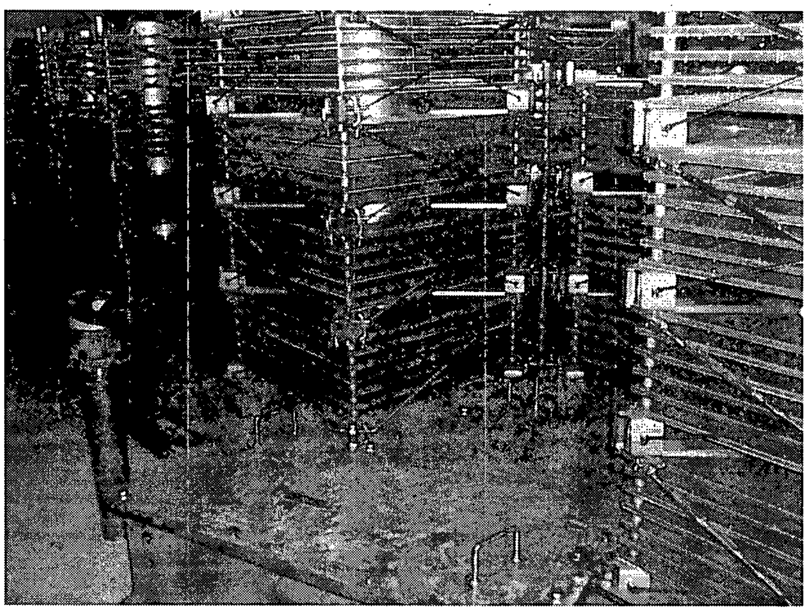
The objective of the screen modification package section is to provide a basic description of the sump screen modification.

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 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 upon top each other to from strainer modules.

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 are as 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 AISI 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 follows:

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 percent 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 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) is as follows:

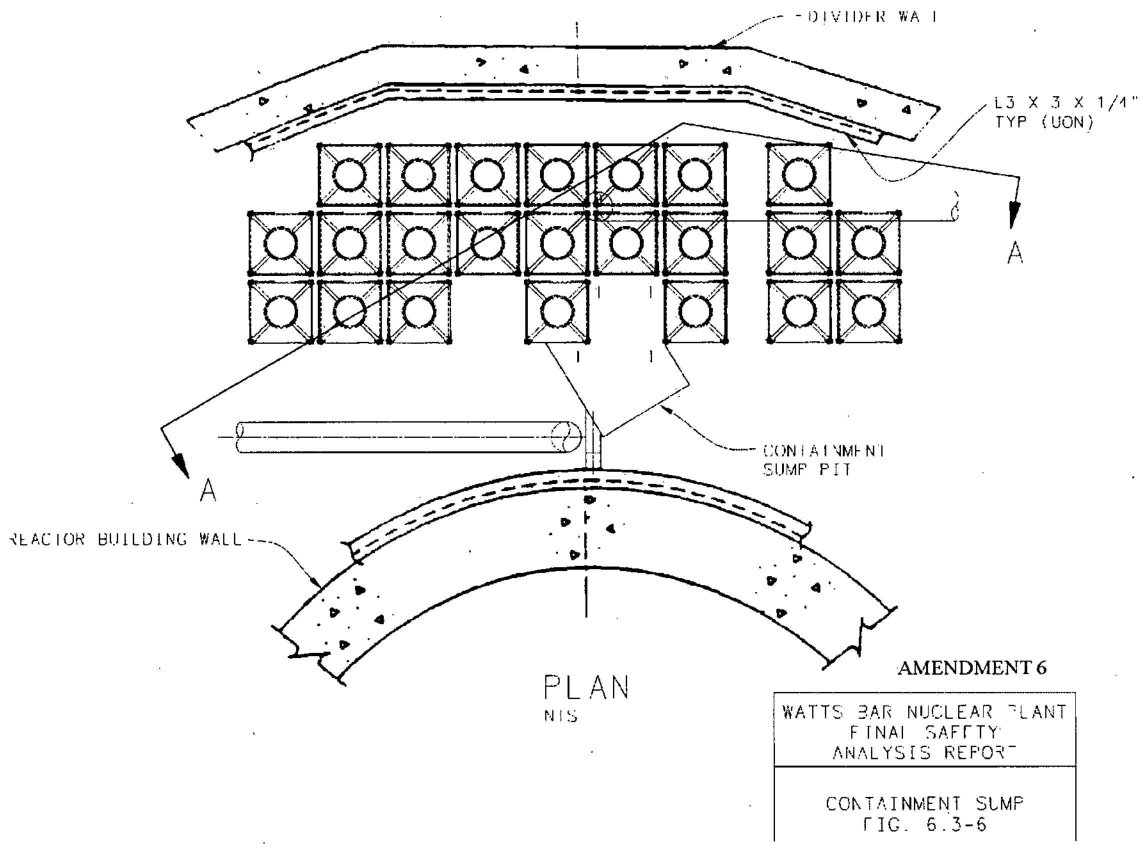
WBN Containment Sump Strainer and Flow Plenum Structural Analysis Interaction Ratios

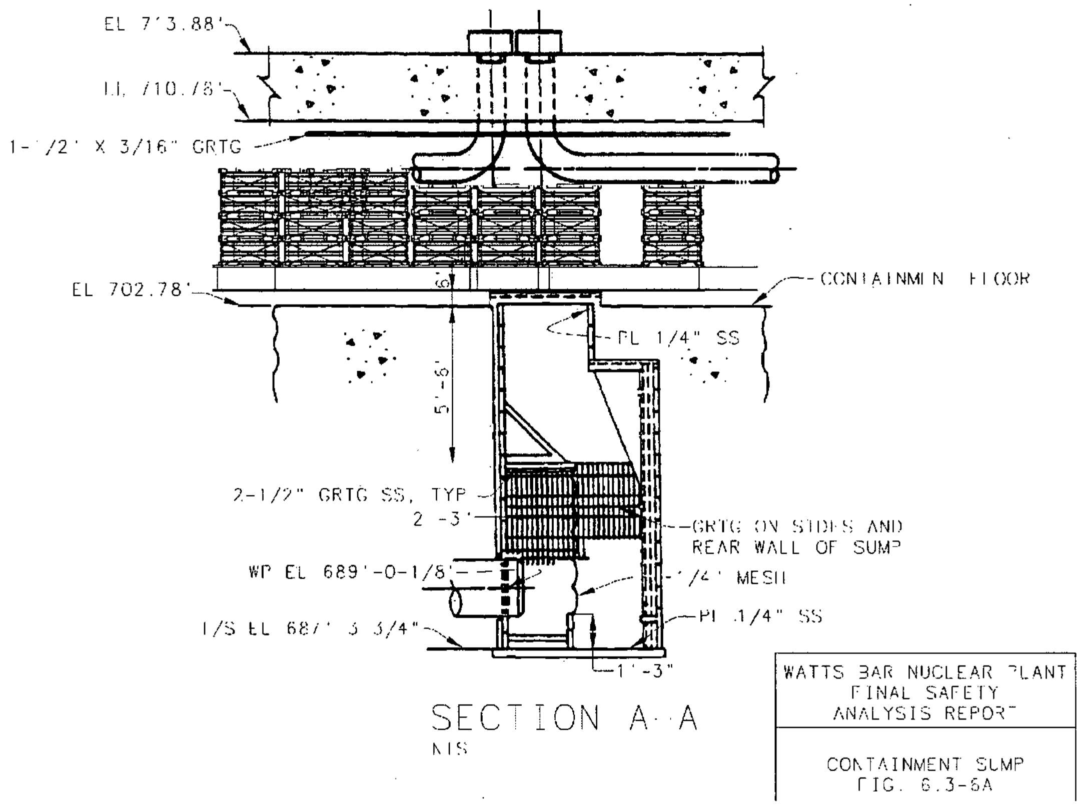
Strainer Component	Maximum Stress Ratio	Flow Plenum Component	Maximum Stress Ratio
Radial Stiffener (w/ Collar)	0.86	Support Beams	0.09
Tension Rods	0.46	Support Floor Beam Local Web	0.95
Edge Channels	0.78	Top Cover Plate	0.84
Cross Bracing	0.41	Lower Deck Plate	0.25
Hex Coupling	0.31	Plate Beam Over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

TVA Response

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 FSAR figure 6.3-6. 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.l. 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).

<u>GL 2004-02 Requested Information Item 2(d) CM</u>
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.

<u>TVA Response (items 1 through 4)</u>

Containment walkdowns were performed in accordance with the guidance in NEI 02-01 in Unit 1 with Unit 2 being 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 potential chokepoints are 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 twenty 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 assure 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 1 through 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 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.

<u>Calculation Note, "Watts Bar GSI Down Stream Effects Debris Ingestion Evaluation"</u>

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.

$$\gamma = 0.0003186$$

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	3 ppm
Particulate	308 ppm
Coatings	593 ppm
Total	904 ppm

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

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 a sump screen hole size of up to 0.25 inches (0.25 inches is used for conservatism, the actual sump screen hole size is 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 vessels 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 904.46 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 Table 2 and Table 3 below.

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. Charging cold leg injection barrel orifices OR-63-854, 850, 851, 852, SI cold leg injection flow barrel orifices OR-63-860, 861, 859, 858, SI hot leg injection barrel orifices OR-63-857, 856, 852, 855 are not installed on WBN Unit 2. Further Charging Pump Header orifice wear and plugging evaluation is required as the WBN Unit 2 orifice is a larger diameter than the WBN Unit 1 orifice. WBN Unit 2 will complete this evaluation of the information denoted below by an asterisk (*) by December 20, 2010.

Flow restricting, wear, and plugging evaluations for the Single plate, multiple plate, and barrel orifices can be found in Table 4 – Table 11 below.

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	0.7958	*	*	*

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	$\Delta Q/Q$	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	TBD

Spray Wear Evaluation:
The number of RHR spray header nozzles required for WBN Unit 2 is 140, less than 142 for WBN Unit 1. Further RHR spray header wear evaluation of the information denoted below by an asterisk (*) is required by December 20, 2010, as this change is not bounded by the WBN Unit 1 calculation. The flow is changed by less than 2.5% for CSS spray header nozzles which is less than the 10% limit, so the nozzles do not fail. See Table 10 for nozzle wear evaluation results.

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	*	*	*	*

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 plugging expected; requires further evaluation

Pump Wear Evaluation:
For pumps, the effect 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. The mechanical shaft seal assembly performance evaluation resulted in the one action item with the suggested replacement of the pumps' carbon/graphite backup seal bushings with a more wear-resistant material, such as bronze. However, since WBN has an Engineered Safety feature (ESF) atmospheric filtration system in its auxiliary building, this action item is not required.

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

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

Calculation Note, "Watts Bar Sump Debris Downstream Effects Evaluation for ECCS Valves"

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 Vulvan (SPX Corporation) class 1513 globe valves. This change eliminated the need for barrel orifices in the injection lines. A debris wear evaluation must be performed for these ECCS valves. WBN Unit 2 will complete this evaluation by December 20, 2010. According to the criteria established in WCAP-16406-P, all remaining ECCS valves pass their respective evaluations. A more detailed summary for these remaining valves can be found below.

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 below.

Table 14: Sedimentation Evaluation

#	System	Customer ID	Type	Size (in)	Min 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	1785	11.48	yes
52	RHR	FCV-74-35	gate	8	1785	11.48	yes
56	RHR	63-633	swing check	6	1000	11.44	yes
57	RHR	63-632	swing check	6	1000	11.44	yes
58	RHR	63-634	swing check	6	1000	11.44	yes
59	RHR	63-635	swing check	6	1000	11.44	yes
60	RHR	FCV-63-93	gate	8	2096	13.49	yes
61	RHR	FCV-63-94	gate	8	2096	13.49	yes
86	RSPRAY	FCV-72-40	gate	8	1556	10.01	yes
87	RSPRAY	FCV-72-41	gate	8	1556	10.01	yes
88	RSPRAY	72-562	check	8	1556	10.01	yes
89	RSPRAY	72-563	check	8	1556	10.01	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 WBN 1 for fibers. The conclusion of the this evaluation indicates that the amount of fibrous debris generated by a large break LOCA 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 WBN 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.

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

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 the WCAP-16793-NP. This WCAP is applicable to and bounds WBN 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 screens 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 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 was 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 WBN 1/2.

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

Comparison of LOCADM Sample Calculation Parameters to WBN 2 Plant Conditions

Parameter	Sample Calculation	WBN 2
Core Thermal Power Rating	3188 MWth	3411 MWth
Fiber (fiberglass) Debris Load	7000 ft^3	6.25ft^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	1146 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 WBN Unit 2 plant conditions.

TVA will complete the Watts Bar in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 six months 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," or six months following the issuance of the NRC guidance described in SECY-10-0113, "Closure Options of Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance," dated August 26, 2010.

WBN Unit 2 will use the alternate p-grid design (or later design) for the robust fuel assemblies (RFA-2) fuel used in WBN 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. ML0726007425).

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.

Table 1: WBN Materials Input

Class	Material	Amount
Coolant	Sump Pool Volume (ft^3)	54907
Metallic Aluminum	Aluminum Submerged (ft^2)	203
	Aluminum Submerged (lbm)	450
	Aluminum Not-Submerged (ft^2)	1146
	Aluminum Not-Submerged (lbm)	2547
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)	20000
Buffering Agent	Sodium Tetraborate (lbm)	0
Interam	Interam (ft^2)	0

* Latent fiber is characterized as fiberglass

Table 2 shows the "Time Temp 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: WBN Time Temp pH Input

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Spray pH	Containment Temp. (°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
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 are used to determine the amount of precipitates formed from the containment materials as shown in Table 3.

Table 3: WBN 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 were 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 16.30 kg as shown in Table 4.

Table 4: Predicted Chemical Precipitate Formation for WBN

Precipitates	kg
$NaAlSi_30_8$	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 Watts Bar Updated Final Safety Analysis Report has been amended to include this information. FSAR Sections 6.2.2.2, 6.3.2.14, and 9.2.7.1 will be updated in a subsequent amendment to remove the assumption that containment water level is at containment floor evaluation for the NPSH analyses for Containment Spray and RHR pumps and to reflect the latest strainer head loss testing results and calculation revisions by December 20, 2010.

Enclosure 2
NRC Audit Open Items

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

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

The revised debris generation analysis, ALION-CAL-TVA-2739-03 Rev 3, "Watts Bar Reactor Building GSI-191 Debris Generation Calculation," was submitted under the Unit 1 docket and applies to Unit 2 with the exception that Unit 2 will not use min-K or 3M fire wrap.

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 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 and 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 above a similar walkdown will be performed for Unit 2 following Unit 2 completion and cleanup of containment for 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

The original NPSH analyses supporting the FSAR demonstrate that adequate NPSH margin exists for the emergency core cooling and containment spray systems. The analyses reviewed by the NRC in the audit (Westinghouse calculation FSDA-C-597, and TVA calculation EPM-RCP-120291) do not credit water levels above the containment floor and are therefore conservative. A revised NPSH calculation was completed with more realistic assumptions to determine a better estimate of available margin. The strainer testing demonstrated very little head loss for all cases tested including a non-mechanistic sensitivity test where all coatings were placed at the screen. However, additional tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations to address NRC strainer testing protocol. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010. Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1 to Enclosure 3 of this document.

Open Item 5

The licensee should provide the final structural analysis report for the replacement strainer.

TVA Response

The final structural analyses were provided under the Unit 1 docket and have since been updated to include Unit 2 as discussed in Enclosure 1, Section 3.k. 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." 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 3.b.4.
calcium silicate debris (80 ft^3)	No Cal-Sil	WB 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 3n above.

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 3m above.

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 downstream impacts were based on U1 initial strainer test results and the test determined bypass fractions. The NUKON fiber used in the strainer test was a surrogate for the latent fiber which was present in very low quantities in the test and confirmed in the latent debris walkdown. A revision to the analysis for downstream debris concentration resulted in a slightly higher concentration used in the final analysis (904 ppm). This provides adequate assurance the evaluations are conservative and is conservative for Unit 2 since Unit 2 does not use min-K or 3M fire wrap.

<u>*Open Item 10*</u>

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 the amount is generally limited (as it is at WBN). "...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."

<u>*Open Item 11*</u>

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 above.

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

Watts Bar 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 question is not applicable to Watts Bar Unit 2.

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

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

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 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010. Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1 to this enclosure.

Flume Velocity and Turbulence

Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1. 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

Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1. 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

Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1. Utilizing the test tank protocol, the following steps are expected to address this section:

- The test tank will be filled with water to the design-basis water level and maintained during the duration of the test.
- Fine fiber will be 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 will then be diluted with enough water such that no clumps will be visually observed.
- The debris will be introduced into the test tank only after the start of the recirculation pump and the designed flow rate has been established. Debris will be 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 will be mixed with heated water with a ratio of 5:1 to ensure debris does not agglomerate. See Attachments 2 and 3 of this enclosure for further discussion of debris preparation and debris dilution to minimize agglomeration.
- A trash pump will be 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

Tests were performed in a test tank and implemented the test tank protocol similar to the protocol shown in Attachment 1. 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%.
- The test may not be terminated if the head loss is displaying a high increase over time. The test may continue until the head loss levels off. Thirty-day head loss extrapolation may be incorporated to determine the maximum head loss.

Any extrapolation of test results will bound test data by explicitly accounting for the effect in the calculation or by demonstrating that existing conservatisms in the minimum level calculation would bound this effect.

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 are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.

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. Therefore, due to the combination of a lack of an air entrainment mechanism (i.e., vortex formation), air ingestion will not occur. Calculation revisions for minimum sump water level are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.

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 Item 3.f.9 of Enclosure 1 to this submittal, the clean strainer head loss across the Watts Bar 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 Performance Contracting Incorporated (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 pressurized water reactor (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. 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 Watts Bar 2, the test results were as follows:

Table 1 - Clean Strainer Head Loss Calculated vs. ARL Test Data		
Test Flow Rate, 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 Watts Bar service conditions. The strainer exit velocity for the test prototype was 7.723 ft/sec. The limiting exit velocity for the Watts Bar strainers is 2.093 ft/sec. Because the Watts Bar strainer exit velocity is less than that for the tested prototype, the Watts Bar 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 Watts Bar strainers. The nominal head loss was then adjusted to conservatively account for additional head losses associated with specific aspects of the Watts Bar 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.

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 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These test further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.

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

Watts Bar 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 question is not applicable to Watts Bar Unit 2.

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 power operated relief valves (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 2235 psig. If the valve is not able to be isolated, the event is no longer a RCS depressurization but a 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 is the contribution from the RCS to the sump volume based on a 2000 gpm SBLOCA. However, the only volume that can get into the Reactor cavity for a 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 CRDM housing, and (c) when the lower compartment water level reaches El. 715' - 8.5". The bottom of the hot leg penetrations are El. 715' - 8.5" and the entrance to the keyway is at El. 716' - 0". The reactor vessel nozzles and the control rod drive mechanism (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.

Watts Bar 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. However, even if the RCS volume is considered holdup volume only, the sump level at switchover would be 6.06 ft. Thus, the use of the smaller LOCA with maximum reactor cavity holdup volume to determine water level at time of switchover, remains conservative. The change in RCS leakage volume due to cooldown from 650°F to 150°F was not adjusted for these cases. WBN Unit 2 will revise this calculation to determine the impact of this change and will update the NRC by December 20, 2010.

Background:

Calculation WBNOSG4071 was provided to the NRC during the NRC Audit of Watts Bar for GL 2004-02. Cases Ia and IIa were added in a later revision and are summarized below.

Case I. 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), Containment Spray (CS) operation on Refueling Water Storage Tank (RWST) level at Residual Heat Removal switchover. The Reactor Building response to a SBLOCA was determined using the MONSTER computer program. The volume of water in the reactor cavity is determined by calculating the time of emergency core cooling system (ECCS) switchover to the containment sump and picking the value of the reactor cavity water volume from the computer code output. This resulted in 2020 gallons in the reactor cavity or 1.67E+04 lbm. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Case I1. 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups, 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 128,000 gallons or 1.06E+06 lbm. 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. 2000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), CS operation on RWST, level at residual heat removal (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 2000 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 42,810 gallons or 3.50E+05 lbm. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Case IIa. 2000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), 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 2000 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 60,573 gallons or 4.95E+05 lbm. 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)	213,600	202,000	293,000	303,000
Water in reactor cavity (RCS leakage)	2,020	42,810	2,470	60,573
Water in refueling canal (ice melt)	12,900	50,752	13,400	76,900
Total inventory	228,520	295,561	308,870	440,473

Holdup	**Volume (gal)**			
Service	Case I	Case Ia	Case II	Case IIa
Containment Spray Piping	2000	2000	2000	2000
Containment atmosphere @ 250 F				
as vapor	6000	6000	6000	6000
as droplets	1280	1280	1280	1280
Holdup on containment floor	8500	8500	8500	8500
Refueling canal holdup (drains not submerged)	9180	9180	9180	9180
Reactor cavity holdup	2020	42,810	128,000 (maximum)	60,573
Pocket sump	395	395	395	395
RHR sump	5080	5080	5080	5080
Total	34,455	75,245	160,435	93,008

Sump level (ft)				
	Case I	Case Ia	Case II	Case IIa
Level at RHR switchover	6.54	7.5		
Level at CS switchover			5.48	11.9

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 Watts Bar in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 six months 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." Based on available margins, it is anticipated that the remaining in-vessel downstream effects issues can be addressed by demonstrating that Watts Bar plant-specific conditions are bounded by the evaluation in the final report. Within six months of issuance of the SE, a submittal will be made documenting the final Watts Bar in-vessel downstream effects evaluation. If this evaluation cannot be completed within six months of SER issuance, a schedule for completing the confirmatory evaluation will be provided.

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

The design basis of the modified emergency sump strainer has been incorporated into the plant's current licensing basis. The Watts Bar Updated Final Safety Analysis Report has been amended to include this information. FSAR Sections 6.2.2.2, 6.3.2.14, and 9.2.7.1 will be updated in a subsequent Amendment to remove the assumption that containment water level is at containment floor evaluation for the NPSH analyses for Containment Spray and RHR pumps and to reflect the latest strainer head loss testing results and calculation revisions in addition to the in vessel downstream effects evaluation by December 20, 2010.

Attachment 1
(to Enclosure 3)

Test Tank Protocol

Attachment 1
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

Attachment 2
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
(to Enclosure 3)

Additional Test Tanking Inputs

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.

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 1part 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

Approach:

CFD results are not used and are not applicable for the test tank protocol.

Enclosure 4

List of Regulatory Commitments

Tennessee Valley Authority
Watts Bar Nuclear Plant - Unit 2, Docket No. 50-391

	Item No.	Commitment	Committed Date
1.	Enc. 1, Items 1 and 3.m	The valves will require separate evaluation for post accident recirculation fluid erosion. This will be completed by December 20, 2010.	12-20-10
2.	Enc. 1, Items 1, 3.f.4, 3.f.6, 3.f.8, 3.f.10, 3.g.6, and 3.h.4; Enc. 2, Open Item 4; Enc. 3, Items 3 and 6	Additional strainer head loss tests were conducted in July 2010 and August 2010 on both the WBN Unit 1 and SQN strainer configurations. These tests further evaluated the performance of the advanced strainer design. WBN Unit 2 will evaluate the implications of these tests with respect to the low debris loadings predicted for Unit 2 and will update the NRC by December 20, 2010.	12-20-10
3.	Enc. 1, Items 2 and 3.g.16	The NPSH calculations will be revised to address the results of strainer head loss testing and clean strainer head loss (CSHL) computational fluid dynamics (CFD) updates.	12-20-10
4.	Enc. 1, Item 3.a.3	Debris generation calculations will be revised for a break in the 31" inner diameter crossover leg at the base of the steam generator for each of the primary system loops. The design basis debris loading supported by strainer head loss testing will bound the worst case RMI debris load with the worst case fiber and particulate load.	12-20-10
5.	Enc. 1, Item 3.d.1; Enc. 2, Open Item 3	A similar confirmatory walkdown will be performed on Unit 2 after containment work is completed and the containment has been cleaned and walkdown for loose debris. This will be done prior to startup.	Prior to Startup
6.	Enc. 1, Items 3.f.2, 3.g.1, 3.f.11, 3.g.16; Enc. 3, Item 4	Calculation revisions for minimum sump water level are expected to confirm that strainer submergence will be demonstrated for all operating conditions. WBN Unit 2 will complete these calculation revisions by December 20, 2010.	12-20-10
7.	Enc. 1, Item 3.m	Further Charging Pump Header orifice wear and plugging evaluation is required as the WBN Unit 2 orifice is a larger diameter than the WBN Unit 1 orifice. WBN Unit 2 will complete this evaluation of the information denoted below by an asterisk (*) by December 20, 2010.	12-20-10

Enclosure 4

List of Regulatory Commitments

	Item No.	Commitment	Committed Date
8.	Enc. 1, Item 3.m	The number of RHR spray header nozzles required for WBN Unit 2 is 140, less than 142 for WBN Unit 1. Further RHR spray header wear evaluation of the information denoted below by an asterisk (*) is required by December 20, 2010, as this change is not bounded by the WBN Unit 1 calculation.	12-20-10
9.	Enc. 1, Item 3.p; Enc. 3, Item 10	FSAR Sections 6.2.2.2, 6.3.2.14, and 9.2.7.1 will be updated in a subsequent amendment to remove the assumption that containment water level is at containment floor evaluation for the NPSH analyses for Containment Spray and RHR pumps and to reflect the latest strainer head loss testing results and calculation revisions in addition to the in vessel downstream effects evaluation by December 20, 2010.	12-20-10
10.	Enc. 3, Item 8	The change in RCS leakage volume due to cooldown from 650°F to 150°F was not adjusted for these cases. WBN Unit 2 will revise this calculation to determine the impact of this change and will update the NRC by December 20, 2010.	12-20-10
11.	Enc. 1, Item 3.n.1; Enc. 3, Item 9	TVA will complete the Watts Bar in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 six months 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," or six months following the issuance of the NRC guidance described in SECY-10-0113, "Closure Options of Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance," dated August 26, 2010.	Six months following issuance of final NRC SER for WCAP-16793-NP or six months following issuance of SECY-10-0113 dated 8-26-10