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

MAR 03 2009

10 CFR 50.54(f)

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

Gentlemen:

In the Matter of	)	Docket No. 50-390
Tennessee Valley Authority	)	

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1 - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MC4730)

By letter dated December 5, 2008 (ADAMS Accession No. ML083370033), the United States Nuclear Regulatory Commission (NRC) submitted a request for additional information regarding TVA's March 31, 2008 Supplemental Response to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," for Watts Bar Nuclear Plant (WBN), Unit 1 (ADAMS Accession No. ML081090500).

This letter provides TVA's response to NRC's request for additional information. Enclosure 1 is a discussion of conservatisms and margins that provides a high level summary of conservatism and margin in TVA's approach to the analysis and testing performed to qualify the WBN sump strainer, which reinforces conclusions of acceptability and margin for the strainer. Enclosure 2 provides the responses to NRC's questions from the request for additional information, as well as corrections to TVA's March 31, 2008 Supplemental Response to Generic Letter 2004-02.

Enclosure 3 provides a listing of regulatory commitments made in this submittal. If you have any questions concerning this matter, please call me at (423) 365-1824.

A116
NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 3rd day of March, 2009.

Sincerely,

M. K. Brandon
Manager, Site Licensing
and Industry Affairs

Enclosures

cc (Enclosures):

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ENCLOSURE 1

CONSERVATISMS AND MARGINS

CONSERVATISMS AND MARGINS

Watts Bar Nuclear Plant (WBN) was one of the first PWR plants to conduct strainer testing. At the time of WBN testing, there was limited industry and NRC guidance regarding testing protocol. Although the strainer test protocol used for WBN contained some nonconservatisms due to limited strainer testing knowledge, it was adequate to ensure the WBN replacement strainer had a large enough screen area to accommodate losses caused by the combination of debris and clean strainer. The conditions are such that a thin bed is unlikely to form, i.e., due to large strainer area, advanced strainer design, low fiber, principally reflective metal insulation (RMI), and a deep water pool. 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 (approximately 4600 ft^2) was selected such that thin bed effect head losses are not expected to occur. Experience has shown that a fibrous layer of approximately 1/8 inch has generally been necessary to create high head losses across flat-plate strainers. To generate significant head losses across strainer designs having complex geometry such as the WBN replacement strainer design, even thicker theoretical accumulations of fibrous debris could be necessary if non-uniform accumulation is achieved.

Head Loss Testing:

- The quantity of fiber used in the WBN strainer tests were 4% more than the analytical values assumed.
- Even with the additional fiber used in the test, the volume of the fiber was not sufficient to form a 1/8 inch uniform thin bed on the replacement strainer.
- Since WBN was a low fiber plant, paint chips were also used in the test in lieu of particulate. The resultant head loss was extremely low.
- WBN testing shows debris deposition onto the strainer was non-uniform and the strainer was bare in many areas. Assuming a 1/8 inch uniform thin bed forms to filter particulates is conservative.
- Although the head loss test plan included a head loss temperature scaling equation based strictly on the difference in viscosity between the room-temperature water in the test flume and water at the elevated temperature conditions analyzed as bounding for the WBN containment pool, the head losses in the test report were not scaled. As room-temperature water has a greater viscosity than hot post-accident sump fluid, applying a viscosity-based temperature scaling approach would have allowed the head losses measured at room temperature to be reduced to account for physical changes in the properties of water at elevated temperatures. However, the test report conservatively did not credit this phenomenon.

Debris Generation:

- 3M-M20C insulation is assumed to have a zone of influence (ZOI) of 11D (11 times the break diameter). However, test results showed virtually no damage at that distance. It is likely that the ZOI is a lower value, resulting in a lower debris source term for 3M-M20C.
- The debris generation calculation conservatively assumes that 3M-M20C will fail as 100% fines. This assumption was necessary since insufficient test data was gathered to support a refined size distribution for 3M-M20C. Due to the configuration of 3M-M20C with a stainless steel backing and organic binder to hold it together, it is highly unlikely that it would fail as 100% fines.

- 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.

Debris Transport:

- The debris transport calculation assumes that 100% of the fiber will be transported to the sump. Given the large containment and deep pool, this is also conservative.
- A combination of the minimum water level at the beginning of recirculation was used along with the maximum flow rates during full recirculation.
- The water level used for recirculation debris transport was 8.21 feet. This is the minimum water level during sump recirculation, and is conservative since the lowest water level is likely to produce the highest velocities and turbulence, and hence the highest transport fractions.
- The water draining from the Reactor Coolant System (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.
- It was assumed that the agitation caused by the ice melt drainage as it reaches the containment pool can be introduced at the bottom of the pool. This approach is conservative since the sunken debris that resides on the floor could be tumbled or resuspended. Additional studies were also performed which introduced the drainage at the surface of the pool in a more realistic fashion with less conservative results.
- It was assumed that the transportable miscellaneous debris addressed in the debris generation calculation including tags and labels 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.
- 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.
- The transport analyses assumed all transported debris would accumulate on the strainer. However, the height of the replacement strainer is such that most floor transport debris is not likely to lift from the floor onto the strainer.
- As the top of the strainer is over 5 ft above the containment floor, it is very unlikely that significant quantities of floor transported debris, such as RMI foils, could be lifted in sufficient quantity to block the upper strainer surfaces.
- Although computational fluid dynamic (CFD) model results show a turbulent region capable of suspending 5 mil paint chips partially encompassing the region of the containment pool where the replacement strainer is to be located, other considerations limit the concern that currently existing quantities of paint chip debris could significantly affect the replacement strainer. These considerations include:
    - Only a portion of the available paint chips would be light enough and thin enough to become effectively suspended.
    - The portion of the replacement strainer outside the turbulent zone would be less vulnerable to paint chip accumulation.
    - The replacement strainer approach velocities may not be sufficient to keep a large fraction of paint chips attached to the strainer's vertical or downward-facing

horizontal surfaces. Thus, to create a possible head loss concern, paint chips would likely need to completely engulf the replacement strainer.
  - The quantity of coatings predicted to fail under the existing qualified coatings program is insufficient to engulf the strainer.

Head Loss Calculation:

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

- Strainer head loss values established from prototype test data were increased by 6 % to bound test measurement uncertainties.
- The various size strainer assemblies have varying clean strainer head loss values. The largest clean strainer head loss value was applied to the design basis head loss calculation.
- The total debris head loss was established using the limiting measured head loss value. This value was produced by a conservative debris load.
- The minimum Net Positive Suction Head (NPSH) margin for WBN is 5.5 ft. Following this minimum value, an additional 6.5 ft of NPSH margin is added by the time the containment spray pumps finish draining down the refueling water storage tank (RWST). As the ice in the ice condenser baskets continues to melt, additional water inventory would be added to the containment pool.

Event Characterization:

- Both trains of Containment Spray System (CSS) and Residual Heat Removal (RHR) (within the computational model) will be in operation since the suction lines from the containment sump to the RHR pumps are totally independent.
- The containment sump fluid is at the design temperature of 190° F. This conservatively high value is used throughout the analyses including both the containment spray and RHR pump NPSH evaluations.
- The pressure in containment will be at 0 psig. No credit is taken for the presence of air in containment prior to the accident as allowed by the approach identified in NEI 04-07, Section 6.4.7.1, based on the law of partial pressures.
- For Small Break Loss of Coolant Accident (SBLOCA), the level at the time of RHR switchover in the containment sump following a SBLOCA is used.
- For SBLOCA, each train of RHR is assumed to receive 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 Safety Injection Pumps (SIPs) and Centrifugal Charging Pumps (CCPs) (approx 2400 gpm) when being supplied by one train of RHR (no RHR flow is discharging directly into the RCS).
- The maximum calculated CSS flow from the sump for each train (5000 gpm) is assumed.
- No credit is taken for containment accident overpressure in determining the available NPSH for sump recirculation operation for WBN.

ENCLOSURE 2

RESPONSE TO 12/5/2008 REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 2004-02

WATTS BAR NUCLEAR PLANT UNIT 1

RESPONSE TO 12/05/2008 REQUEST FOR ADDITIONAL INFORMATION

REGARDING GENERIC LETTER (GL) 2004-02

In addition to the responses provided below, Attachment 1 to this Enclosure provides corrections to WBN's Supplemental Response to GL 2004-02 (ADAMS Accession No. ML081090500). These corrections are being made as a result of refined assumptions for debris, the revised clean strainer head loss value and revised value for NPSH margin during recirculation. Attachment 1 responses supersede the responses previously submitted in WBN's Supplemental Response to GL 2004-02.

Responses to 12/5/2008 Requests for Additional Information:

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

An experimental program was developed and undertaken specifically for the Watts Bar Nuclear Plant (WBN) to demonstrate that the performance of insulation used inside the containment building at WBN precludes the generation of debris within a prescribed zone of influence (ZOI) when subjected to jet impingement loads such as those projected to occur due to a large break loss of coolant accident (LOCA). Insulation in this experimental program included jacketed Min-K thermal insulation, 3M® Fire Barrier insulation, and jacketed surrogate Min-K insulation.

The two (2) types of protective barriers included:

- 3M Fire Barrier insulation used as radiant energy shield for conduit protection from fires inside Containment
- Min-K insulation used as a thermal shield for conduit protection from adjacent hot pipes

3M-M20C (3M Fire Barrier insulation): Three layers of the 3M-M20C insulation is mounted on a 2-inch conduit which is sealed/tack welded with caps at the ends to prevent movement during the test. The insulation is installed with stainless steel tape to be applied on all exposed edges on each layer. The sample is banded with 0.5 inch wide stainless steel bands at a center spacing of 4 inches. The 3M-M20C insulation test specimen provided used the same installation drawings that are used to install the 3M-M20C at WBN. A 2 inch conduit was chosen because this is the typical size that the majority of which 3M-M20C is installed on. Other actual targets would include the 3M-M20C installed over junction boxes. However, it was determined that the geometry, location and installation of the 3M-M20C on the junction boxes would provide a more robust target than the conduit and allow it to resist damage from steam impingement.

Min-K Insulation (surrogate Min-K Insulation): A surrogate material is used for the Min-K insulation. Fiberglass insulation, Delta Lamella, with Foil-Scrim-Kraft (foil side out) covering with a density of 3 lb/ft^3 is considered conservative with respect to Min-K since it was damaged more easily. The insulation is layered inside a reflective metal outer cassette with an outer diameter (OD) of approximately 11 inches. Inside the cassette are 3 layers of the fiberglass insulation. Each layer is approximately 0.5 inch thick for a total insulation thickness of 1.5 inches. The inner layer is then lined with a stainless steel sheath. This configuration encapsulates the fiberglass insulation with stainless steel material as is typical of encapsulated Min-K insulation installed in WBN. The insulation is mounted on a 6 inch pipe which is sealed / tack-welded with caps at the ends to prevent movement during the test. The sample is banded with 0.5 inch wide stainless steel bands at a center spacing of 6 inches. The 6 inch pipe diameter is typical relative to the targets closest to the break location. The Min-K insulation test specimen provided used the same installation drawings that are used to install Min-K at WBN.

The experimental program took advantage of and used a facility capable of generating a subcooled jet that was representative of the range of temperatures and pressures associated with a postulated large-break LOCA. The supply tank fluid was held at 2000 psig prior to and at the initiation of testing. This pressure precluded a reactionary overpressure condition in the supply tank when jet flow was initiated that would have exceeded safety limits. Testing compensated for this slightly lower supply pressure by locating the test articles relative to the jet nozzle such that the stagnation pressure at the point of jet impingement in the test was calculated to be the same as with a supply pressure of 2250 psia.

The placement of the test article from the jet nozzle was calculated using the ANSI/ANS 58.2-1988 jet expansion model. This was accomplished as follows:

1. First, calculate the stagnation pressure isobars for spherical-equivalent ZOI's of interest with the supply pressure at 2250 psia.
2. Recalculate the same stagnation pressure isobars for spherical-equivalent ZOI's with the supply pressure at 2000 psig.
3. The location of test articles from the jet nozzle was then taken as the distance between the intersection isobars with the centerline of the jet and the jet nozzle outlet itself.

A total of three (3) jet impingement loading tests were conducted. The association of test articles to the corresponding ZOI's tested is given in Table 1-1, "Summary of WBN Jet Impingement Tests." Also listed in Table 1-1 is the distance of the test article from the jet nozzle. For the purpose of testing, the debris generation was defined as the observable release or extrusion of insulation from the jacketed encapsulation. For the purposes of the testing of the Min-K and surrogate Min-K insulation system, debris generation was defined as the observable release or extrusion of Min-K from the woven "pillow" containing the Min-K insulation material. Post-test observations of the tested articles are summarized as follows:

1. For the radiant energy shield, no apparent loss of 3M Fire Barrier insulation (banded) was observed to occur due to jet impingement at the distance from the jet nozzle that was tested.
2. For the thermal shield, a loss of Min-K insulation (not banded) was observed to occur due to jet impingement at the distance from the jet nozzle that was tested.
3. The thermal shield was observed to remain intact with no apparent loss of surrogate Min-K insulation (banded) material following the jet impingement at the distance from the jet nozzle that was tested.

In summary, for the Jacketed Min-K test, the metal jacket came apart, the buckles broke, and the actual jacket was bent but not torn. The insulation was scattered up to a distance of 150 feet downrange and no insulation remained on the mounting pipe. Overall, 15 strips of insulation were intact (3 foot lengths) and 26 strips of insulation were damaged (shredding was evident in damaged pieces).

For the 3M Fire Barrier insulation test, the stainless steel backing was intact. There was slight tearing on each end of the stainless steel backing and the stainless steel tape was gone on the ends. The banding was intact and in the original positions. The stainless steel backing was pushed upward on each end where the bands were loose.

For the Jacketed Surrogate Min-K insulation test, the jacketing was punched in at the point of jet impingement. The latch remained closed but became disengaged, but the bands were still engaged and intact. All the bands stayed in place; except for the band next to the latch (this band was loose and able to be moved pre-test). The latch at the back of the specimen was closed and engaged. A small piece of surrogate material was protruding out between the jacket and end washer on the left side.

Table 1-1 Summary of WBN Jet Impingement Tests

Fluid Supply Pressure = 2000 psig Nozzle Size = 3.5 inches Fluid Supply Temperature = 530° F (nominal target value)	
Test Articles	**Equivalent Spherical Zone of Influence (ZOI) (Distance from jet nozzle in test)**
Min-K Thermal Insulation	10 D (10.4 feet)
3M Fire Barrier Insulation	11 D (11.6 feet)
Min-K Surrogate Insulation	10 D (10.4 feet)

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 believes 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

The revised debris generation analysis, ALION-CAL-TVA-2739-03 Rev 4, "Watts Bar Reactor Building GSI-191 Debris Generation Calculation," is provided in Attachment 2 to this Enclosure. Revision 4 refined the assumptions associated with 3M-M20C such that the bounding case for the amount of 3M-M20C is 8.45 ft^3 with a distribution of 35% LDFG fibers and 65% vermiculite particulate. The distribution is based upon the nominal amounts by weight as specified in the 3M-M20C MSDS. Further, laboratory analysis of the 3M-M20C mat was performed to validate the composition. The sample was examined for 4 nonmetallic components. Brown and yellow flakes were verified to be vermiculite (particulate). Clear beads were verified to be aluminum silicate (fiber). Ceramic fibers were verified to be fiber glass (fiber). The organic binder for the vermiculite, aluminum silicate and fiber glass was verified to be poly (ethyl acrylate) (particulate). The metal foil wrap is considered particulate. The amount of 3M-M20C used to perform WBN's strainer performance test was scaled to the test module based upon an expected quantity of 9.15 ft^3. The debris generation calculation bounding case for the amount of Min-K is 31.7 lbm. The amount of Min-K used to perform WBN's strainer performance test was scaled to the test module based upon an expected quantity of 51.2 lbm. As can be seen by photos taken of 3M-M20C prior to the test, it was shredded such that any fibers would not have agglomerated and would have sufficiently transported to the test strainer. Thus, any impacts on strainer head loss would have been accounted for based on actual test results instead of imposed assumptions.

Vermiculite contains a nominal value of 42% SiO_2. 3M-M20C contains a nominal amount of 50% vermiculite, resulting in 164.8 lbm vermiculite and 69.2 lbm of SiO_2. WBN fiber sources are such that a 1/8 inch thin bed does not form based on actual fiber sources (i.e., 48.1 ft^3 LDFG equivalent 3M-M20C, 0.4 ft^3 Min-K, 0.1 ft^3 actual latent fiber debris). WBN actual strainer surface area is 4675.1 ft^2 rounded down to 4600 ft^2 for conservatism. Even with an assumed latent debris source of 12.5 ft^3 fibrous materials, the conservatisms assumed within the debris generation and debris transport calculations make it highly unlikely that a thin bed of fiber would form. These assumptions include:

1. 3M-M20C is assumed to have a ZOI of 11D. However, test results showed virtually no damage at that distance. It is likely that the ZOI is a lower value, resulting in a lower debris source term for 3M-M20C.
2. The debris generation calculation conservatively assumes that 3M-M20C will fail as 100% fines. This assumption was necessary since insufficient test data was gathered to support a refined size distribution for 3M-M20C. Due to the configuration of 3M-M20C with a stainless steel backing and organic binder to hold it together, it is highly unlikely that it would fail as 100% fines.
3. The debris transport calculation assumes that 100% of the fiber will be transported to the sump. Given the large containment and deep pool, this is also conservative.
4. WBN testing shows that debris deposition onto the strainer was non-uniform and that the strainer was bare in many areas. Assuming that a 1/8 inch uniform thin bed forms to filter particulates is conservative.

Based on these conservative assumptions and test results using actual material, the refinements made to the assumed characteristics of 3M-M20C do not affect the conclusions of the strainer performance analysis.

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

Fibrous Debris Preparation and Introduction with Respect to Prototypical Sizing (Transport and Bed Formation)

The fibrous debris tested for WBN was 3M-M20C, Min-K, latent fiber, and paper tags. For each of the tests, processed 3M-M20C, Min-K and finely shredded NUKON (surrogate for latent fiber) were used. The fiber from paper included in the testing consisted of standard paper cut into 2 inch squares. The NUKON was prepared by shredding large sheets of NUKON using a wood chipper. The smaller clumps of NUKON were then separated by hand before the premixing of the fibrous debris to further reduce the size. Figure 1 shows the tin substitute, Min-K and 3M-M20C material prepared prior to being stirred and mixed with water. Based on information discovered after the head loss testing, 3M-M20C is no longer assumed to be 100% individual fibers. It is 65% particulate and assumed 35% fibrous. Thus, the debris size distribution of the actual material used in the head loss test was representative.

Figure 1

The fibers were mixed in water separately using a mixing device. Following reflective metal insulation (RMI) debris introduction into the test flume, the pre-mixed fibrous debris was added into the test flume. Manual mixing was of the test flume was performed before the recirculation pump was started.

Following completion of Test 2, with the pump continuing to run, additional latent fiber was added in the vicinity of the strainer. The additional latent fiber was hand-separated shreds that were subsequently mechanically stirred and mixed with water prior to introduction into the flume. It is conservative to assume that the hand-separated fiber would behave similarly to the blender-processed NUKON. Blender-processed NUKON is generated by stirring shredded NUKON using a kitchen blender to separate the fibers and prevent clumping per NUREG/CR-6885. Thus, since the shredded NUKON was hand-separated into individual fibers and then stirred with a mechanical mixer, the number of individual fibers would be sufficiently fine to represent transport of the individual fibers in the test flume. The additional fiber was introduced within a one foot radius of the strainer to ensure that 100% of the fiber transported to the strainer. Figure 2 shows that the additional fiber which primarily accumulated on top of the strainer, there is still free screen area - demonstrating that a fiber layer that is capable of efficiently filtering particulate would not accumulate on the strainer. The flow rate was increased approximately 2 times that of the designed flow rate and the resulted head loss was still insignificantly low (0.27 ft). Figure 3 below is a photograph taken after completion of Test 2. The photograph shows that even with the additional fiber and the increased flow rate, free screen area exists on the WBN test strainer indicating WBN strainer surface area is large enough to accommodate the additional fiber and increased flow rate.

Figure 2

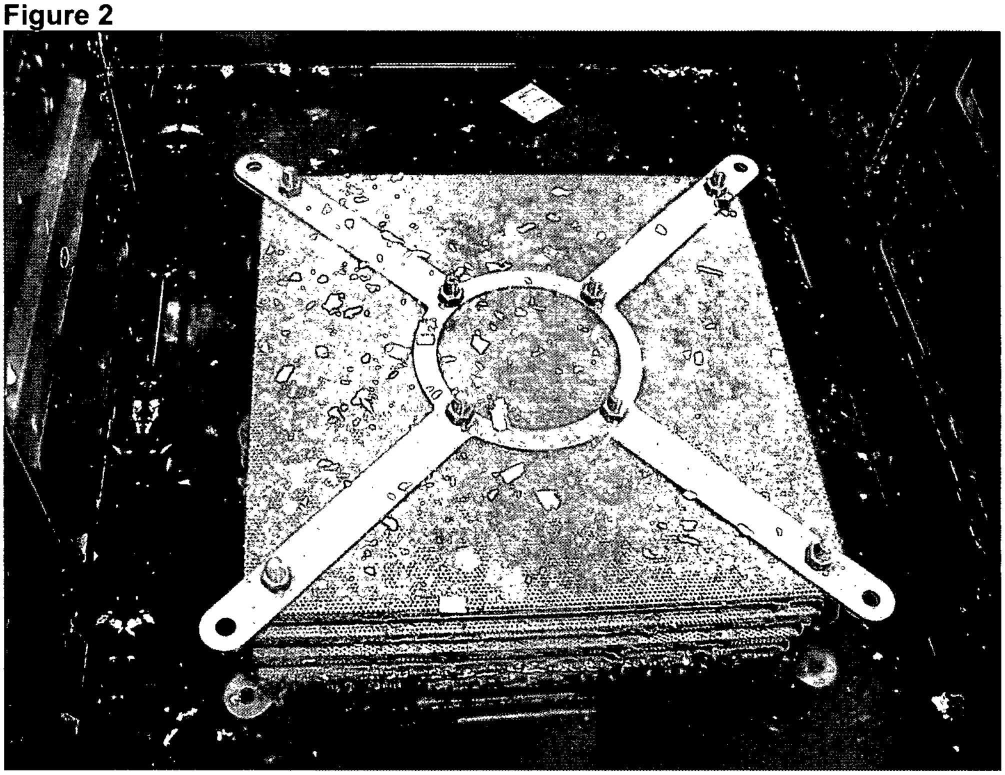
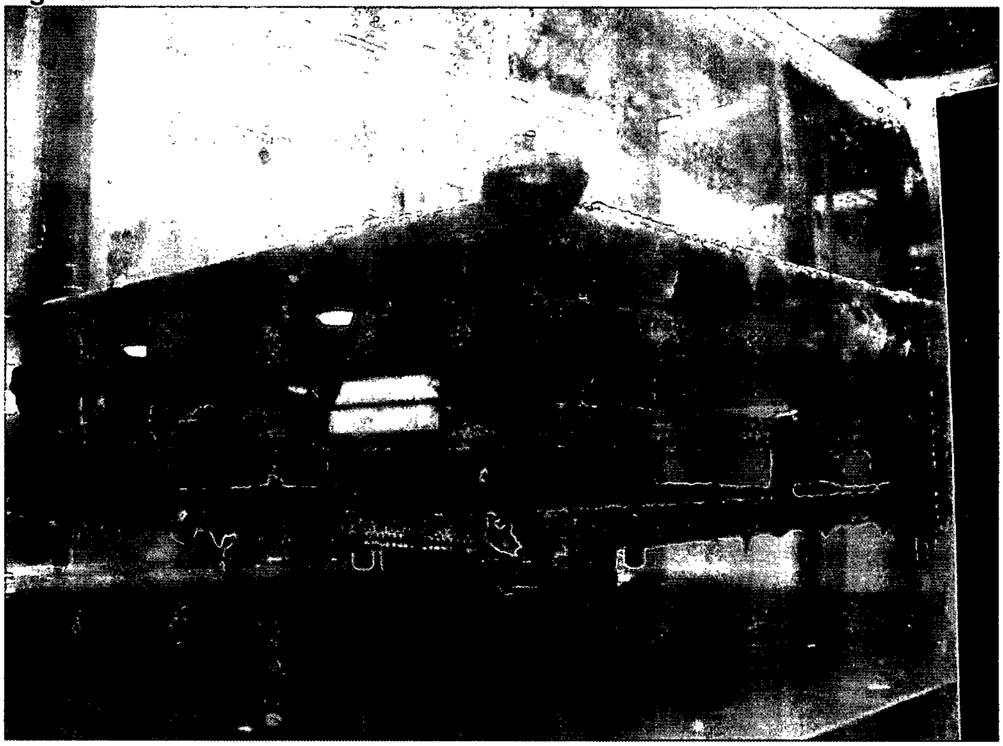


Figure 3



Flume Velocity and Turbulence

The unique design characteristics of the PCI Sure-Flow Suction Strainer result in a constant approach velocity to the strainer under all debris loading conditions without exception. This is a unique characteristic specifically associated with the PCI Sure-Flow Suction Strainer that the patent recognized, and which other large passive strainer designs without Suction Flow Control Device (SFCD also known as the core tube) can neither claim nor substantiate. The design employs a SFCD that is the core tube that uniformly distributes the flow energy of the strainer uniformly over the length of the assembly. The fluid approach velocity to the strainer assembly can be accurately modeled with a small scale replica of the strainer using the same fluid approach velocity. Debris laden fluid does not change the scaling or modeling effects of the strainer.

The test flume flow velocity was 0.036 ft/sec. The target flow rate for the test was 67.6 gpm or 0.15 ft^3/sec (the actual test flow rates were conservatively kept slightly higher than the target flow rate) to match the maximum strainer approach velocity. The test flume width was 27 inches or 2.25 feet and the water height in the test flume was 22 inches or 1.83 feet (Velocity = Flow ÷ Cross Sectional Area = 0.036 ft/sec).

With respect to flume turbulence, overhead nozzles were used to fill the flume after debris introduction was completed to help maintain the debris in suspension and maximize debris transport to the strainer. The spray was not used after the recirculation pump started. The Reynolds Number for the flow in the test flume was 1779. For open channels such as the test flume, this value represents transitional flow between laminar conditions (Re < 500) and turbulent conditions (RE > 12,500). Transitional flow inside the test flume is considered conservative since it imparts some energy on the debris to help breaking up the agglomeration but not too much energy, as would turbulent flow, which may breakup or prevent the debris bed formation on the strainer surfaces contributing to the strainer head loss. Even though WBN refueling canal drains are located just outside the strainer, this was conservatively not simulated during the test such that the turbulent flow would not prevent debris bed formation.

Test Scaling (Debris Amounts and Strainer Flow Velocity)

Scaling of debris amount:

The scaling factor used in the WBN strainer qualification testing was computed, based on debris per unit screen area, as follows:

$$\text{ScalingFactor} = \frac{\text{StrainerTestScreenArea}}{\text{DesignedStrainerScreenArea}} = \frac{16.1}{4{,}550} = 0.00358$$

Each of the debris amounts used in the WBN strainer qualification testing was determined by multiplying the designed amount by the scaling factor of 0.00358. The scaling based on debris per unit screen area is considered acceptable since the core tube design of the SURE-FLOW® strainer creates uniform flow across the strainer arrays. This would allow for uniform debris loading on the strainer surfaces. Therefore, scaling based on debris per unit area is acceptable

Strainer flow velocity:

Strainer flow velocity was not scaled. The approach velocity for the test strainer screen surfaces was the same as that of the designed strainers. The velocity was determined as follows:

$$\text{StrainerVelocity} = \frac{\text{DesignFlowRate}}{\text{DesignStrainerArea}} = \frac{19{,}100\text{gpm}}{4{,}550\text{ft}^2} * \frac{1\frac{\text{ft}^3}{\text{sec}}}{448.83\text{gpm}} = 0.0094\frac{\text{ft}}{\text{sec}}$$

Using the velocity of the 0.0094 ft/sec and the test screen area of 16.1 ft^2, the test flow rate was calculated as follows:

$$0.0094\frac{\text{ft}}{\text{sec}} * 16.1\text{ft}^2 * \frac{448.83\text{gpm}}{1\frac{\text{ft}^3}{\text{sec}}} = 67.6\text{gpm}$$

Note that the flow rate was conservatively kept slightly higher than 67.6 gpm during the test to ensure that the flow rate would not drop below 67.6 gpm due to flow fluctuations.

Near-Field Settling

During the WBN strainer testing, the debris introduction zone was 3 ft to15 ft upstream of the test strainer. Following completion of Test 3-Maximum Coating, the debris was pushed on top of the strainer and the flow rate was increased 2 times that of the design flow rate. The resultant head loss was minimal, indicating that the debris types and amounts (mostly RMI and very low fiber) generated very low head loss although the mixed debris was place directly on top of the test strainer. However, WBN is currently maintaining the qualified coatings program intact as described in FSAR Section 6.1.4.

Debris Addition into the Test Flume

The following steps were performed for debris addition into the test flume:

- The flume was filled to an approximate depth of 6 inches. This is conservative since it helped keep the debris in suspension and prevent settling on the flume floor.
- Premixed debris with water in buckets or large trash cans was added into the flume. The debris was added into the test flume 3 to15 feet upstream of the strainer. This distribution pattern was conservatively selected to maximize debris transport to the strainer and minimize debris agglomeration. RMI debris was added before the other debris types (fibrous and particulate) were added. Adding the RMI debris before fibrous debris is conservative since the heavier RMI debris may blanket or cover the fibrous debris preventing it from transporting to the strainer. Note that WBN containment contains mostly RMI insulation with very little fiber insulation.
- Once all of the debris was added, filling of the test flume was resumed using the overhead spray nozzles until the full testing water level was reached. The use of the overhead nozzles was conservative since it helped ensure the debris was mixed in the flume and minimized debris agglomeration prior to the start of the recirculation pump.
- To ensure the mixed debris was introduced in to the strainer flow stream, manual mixing was performed using a paddle or equivalent before the start of the recirculation pump. This was conservative since manual mixing ensured the debris did not agglomerate prior to the start of the recirculation pump.

Debris Concentration in the Test Flume with Respect to Agglomeration and Settling

During the WBN strainer testing, the debris introduction zone was 3 ft to 15 ft upstream of the test strainer. The purpose of spreading the debris along the length of the test flume was to minimize debris agglomeration. The heavier debris such as RMI settled readily. For this reason, RMI was introduced into the test flume before fibrous debris to prevent the heavier RMI from holding down (blanketing) the lighter fibrous debris from transporting towards the strainer. To further breakup the agglomeration, manual mixing was performed using a paddle or equivalent before the start of the recirculation pump.

During the WBN strainer qualification testing, following completion of Test 3 (Maximum Coating Inventory), with the pump running the debris was pushed towards the strainer forming a mound that completely covered the strainer. The resulted head loss for this test was very low even with the flow rate doubled that of the design flow rate.

Head Loss Test Termination Criteria

Since WBN considers the entire volume of fibrous debris to reach the strainer, slow erosion of fibrous debris on the containment pool floor by flowing water, is not a significant concern. Furthermore, an additional 6.5 ft of Net Positive Suction Head (NPSH) margin is added by the time the containment spray pumps finish draining down the refueling water storage tank. As the ice in the ice condenser baskets continues to melt, additional water inventory would be added to the containment pool. With the addition of this inventory, even if the head loss continued to increase at a slow rate, it is not credible that the cumulative head loss increase would exceed the large increase in NPSH margin provided by this additional water inventory.

Downstream Sampling Procedures

All downstream effects analysis conservatively uses a 5.0% bypass fraction with the exception of CN-CSA-05-36 Rev. 2, WBN GSI-191 Downstream Effects Fuel Evaluation. This calculation note currently concludes that a total fiber load of 88.4 ft^3 with a bypass fraction of 2.42% of which 90% of the fibers were too short to wrap around the support grids. However, if WBN assumed the standard conservative bypass fraction of 5.0% with a total fiber load of 60.96 ft^3 (using refined assumption for 3M-M20C) and also assumed that only 70% of the fibers would pass through based on length, WBN would continue to meet the acceptance criteria of less than 0.125 inches of fibrous debris buildup on the underside of the fuel bottom nozzle. In summary, the potential nonconservatism of not obtaining a higher concentration of debris during the strainer pass-through testing has little to no impact on WBN's downstream effects analysis.

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 most limiting water level for a SBLOCA is for a break inside the reactor cavity with a flow rate of 120 gpm. The water level above the containment floor for this case is 5.48 ft. WBN strainer design contains "tall" strainer stacks and "short" strainer stacks. The top of the "tall" strainers above the containment floor is 5.54 ft. The top of "short" strainers above the containment floor is 4.83 ft. Since the "short" strainers are fully submerged during a SBLOCA, vortex or air ingestion will not occur. The "tall" strainers would be approximately 3/4 in un-submerged for the postulated 120 gpm SBLOCA.

All of the strainer module disks for WBN are a nominal 9/16 inch thick and are separated 1 inch from each adjacent disk. The interior of the disks contain rectangular wire stiffeners for support, configured as a grill made up of three layers of wires. The disks are completely covered with perforated plate having 0.085 inch holes. The end disk of a module is separated by approximately 2.5 inches from the end disk of the adjacent module. The 2.5 inch space between adjacent modules is covered with a solid sheet metal "collar". Each of the modules has cross-bracing on all four exterior vertical surfaces of each module.

Based on the design configuration of the WBN strainer assembly, the largest opening for water to enter into the sump is through the perforated plate with 0.085 inch holes. The perforated plate is the best and primary vortex breaker associated with the strainer. The size of the perforated plate holes by themselves would preclude the formation of a vortex. Air in addition to the water would have to flow through the perforated plate openings. The openings are sufficiently small enough that any air column formed by a vortex would be eliminated because of the surrounding water. However, in the unlikely event that a series of mini-vortices combined in the interior of a disk to form a vortex, the combination of the wire stiffener grill and the small openings and passages that direct the flow of water to the strainer core tube would further preclude the formation of a vortex in either the core tube or the sump.

Regulatory Guide 1.82 specifies that standard 1.5 inch or deeper floor grating or its equivalent has the capability to suppress the formation of a vortex with at least 6 inches of submergence.

Due to the close spacing of various strainer components and the small hole size of the perforated plate, the design configuration of the PCI Sure-Flow® suction strainer for WBN meets and/or exceeds the guidance found in Table A-6 of Regulatory Guide 1.82. For the postulated SBLOCA, the WBN strainer configuration results in the exposure of approximately 3/4 inch of the strainer stack top module for the "tall" strainers. However, due to the fact that the sump water must flow to the core tube through a horizontal path of approximately 6 inches consisting of the combination of disk perforated plates, wire stiffener grills, and cross-bracing would singularly and collectively preclude the formation of a vortex. In addition, there is a 1/4 inch mesh stainless steel screen installed vertically in front of the sump outlet piping providing another layer of vortex suppression.

In conclusion, although the "tall" strainers would be approximately 3/4 inch un-submerged for the most limiting SBLOCA, vortex formation will not occur.

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.

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 the WBN Generic Letter 2004-02 Supplemental Response (ADAMS Accession No. ML081090500), the clean strainer head loss across the WBN strainer assemblies was based in part on prototype strainer head loss test data. The Boiling Water Reactor Owners Group (BWROG) performed testing on a number of advanced design containment sump strainers at the Electric Power Research Institute (EPRI) Charlotte Non-Destructive Examination Facility in 1995. Included in the testing was a prototype "stacked disc" strainer designed and manufactured by 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 WBN, 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 WBN service conditions. The strainer exit velocity for the test prototype was 7.723 ft/sec. The limiting exit velocity for the WBN strainers is 2.093 ft/sec. Because the WBN strainer exit velocity is less than that for the tested prototype, the WBN calculated values contain an additional measure of conservatism.

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

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

Maximum Postulated Strainer Head Loss:

Excess NPSH for Containment Sump Recirculation Operation at RHR Switchover:

System	Flow Rate (gpm)	Total Strainer Head Loss	Available NPSH Margin
RHR	9,100	3.65 ft	7.6 ft
CS	10,000	3.65 ft	5.5 ft

Below are assumptions used to support the maximum head loss calculation:

- A flow velocity of <0.014 fps would be characteristic of the WBNP strainer, through a debris bed consisting of fibers and particulate is 100% viscous flow. Accordingly, the head loss is linearly proportional to dynamic viscosity.

- A scaled strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer so long as the same scaling factor is used for the strainer area, water flow rate, and debris quantities. The scaling factor is defined as ratio of the surface area of the scaled strainer and the surface area of the full scale production strainer.

- The head loss resulting from flow through a fiber-particulate debris bed at the approach velocity for the WBNP strainer (<0.014 ft/s) is 100% viscous flow, as apposed to inertial flow. As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. Therefore, to adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature.

- The total strainer head loss can be calculated by taking the sum of the calculated value of the Clean Strainer Head Loss and the temperature adjusted, testing debris head loss.

- The WBNP specification provides a summary of the various fiber and particulate constituents that are to be addressed during the prototype strainer testing at Alden Research Laboratory. A number of the subject constituents, such as Min-K (the trade name for a microporous insulation material) and 3M-M20C (the trade name for a fireproofing material) are not addressed in the USNRC, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02 or the NEI 04-07 Volumes 1 & 2, with respect to various parameter, such as, the density (bulk and micro), size, and length, etc. Accordingly, based on PCI's experience and specific knowledge of the development of NEI 04-07, assumptions were made with regard to both the classification of the debris constituents – fibers or particulate, as well as their associated density and size. These assumptions are conservative and are supported by the WBNP prototype test results achieved at Alden Research Laboratory.

Evaluation of Potential Flashing Across or Inside the Strainers:

Following a design basis large break LOCA, the recirculation water inside containment is at saturation condition at the surface of the water level. The condition is sub-cooled below the water surface due to the water column above it. At the start of ECCS sump recirculation operation, the ECCS flow rate is 9,100 gpm and the water level is 9.02 ft above the containment floor. The post LOCA containment pressure is conservatively assumed to be atmospheric pressure of 14.69 psia. The top of the tallest WBN strainers is 5.54 ft above the containment floor. Therefore the water column above the top of the tallest strainers is approximately 3.48 ft (9.02 ft – 5.54 ft). If flashing were to occur, it would most likely initiate near the top screen surface of the tallest strainer modules if the head loss across this area were to become greater than 3.48 ft.

The highest total head loss (clean strainer + debris loaded) across the strainer was calculated to be 3.65 ft of water at 120°F using the total (ECCS + CSS) flow rate of 19,100 gpm.

Since head loss is proportional to velocity squared $\left[h_f = K\frac{V^2}{2g}\right]$, the total head loss for the ECCS flow rate of 9,100 gpm can be approximated. Note that flow rates are used instead of velocities since the strainer area is the same for the two different flow rates. The loss coefficient, K and the 2g terms cancel out, yielding:

$$h_{ECCS} = 3.65ft\left[\frac{9{,}100gpm}{19{,}100gpm}\right]^2 = 0.83ft$$

Note that the loss constant, K, is not the same for the two different flow rates since the debris beds on the strainer are expected to be different, but this difference does not negate the qualitative results presented below. Additionally, detailed calculations must be performed to ensure that the flows are independent of the Reynolds number. Therefore, the above estimated head loss of 0.83 ft represents the significant drop in head loss at the lower ECCS flow rate of 9,100 gpm. It is not intended to be used as an input to any design documents without further analysis.

Given that the containment pressurization due to LOCA conditions is conservatively ignored, the head loss across the strainers would have to be greater than 3.48 ft for flashing to occur across or within the strainers. For these conditions, the head loss across the strainers is approximately 0.83 ft. As such, sufficient head margin exists to preclude flashing inside or across the strainer.

Furthermore, at the WBN CSS initiation, the combined flow rate (ECCS + CSS) is 19,100 gpm and the water level is 12.07 ft which is approximately 6.5 ft (12.07 ft – 5.54 ft) above the top of the tallest strainers. At this water level, the total head loss of 3.65 ft is less than the 6.5 ft submergence. Therefore, flashing inside or across the strainer is not expected.

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

No surrogates were required for Interam fire barrier material 3M-M20C. Nukon thermal insulation was used as a surrogate for latent fibers only and was not used as a surrogate for fire barrier material.

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

Background:

Calculation WBNOSG4-071 was provided to the NRC during the NRC Audit of WBN for GL 2004-02. Cases Ia and IIa were added in a later revision and are summarized below.

Cases I, Ia, II, and IIa, assume there is a small break LOCA inside the reactor cavity, limited ice melt from the ice condenser, no accumulator injection, maximum holdup volumes (except for the reactor cavity for cases I, Ia and IIa), and the containment spray system is operating on the RWST at the initiation of auto-switchover. The RHR system is not drawing suction from the RWST since it is operating in miniflow due to normal or near normal RCS pressures. The CCPs and SIPs are taking suction from the RWST. Cases I and Ia are used to determine the containment sump level at RHR switchover. Cases II and IIa are used to determine the containment sump level at CS switchover.

For Case II, the long term RHR containment sump level is calculated considering a passive failure outside the crane wall in the RHR or SIS piping. The containment spray and RHR system is taking suction from the RHR sump, at a total sump flow rate of 11,800 gpm and the balance of the conditions are as for Case I.

For Cases Ia and IIa, a 2000 gpm break is assumed (Cases I and II are for a 120 gpm break). These cases have the same assumptions as Cases I and II, but it is assumed that the only source of water into the reactor cavity is the RCS leakage of 2000 gpm.

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 WBN in-vessel downstream effects evaluation discussed in the supplemental response to Generic Letter 2004-02 upon 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 WBN plant-specific conditions are bounded by the evaluation in the final report. Within 90 days of issuance of the SE, a submittal will be made documenting the final WBN in-vessel downstream effects evaluation or a schedule will be provided for completing the confirmatory evaluation.

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 WBN Updated Final Safety Analysis Report has been revised to include this information as part of the modification implementation process. FSAR Sections 6.2.2.2, 6.3.2.14, and 9.2.7.1 will be revised to remove the assumption that containment water level is at containment floor evaluation for the NPSH analyses for Containment Spray and RHR pumps. These FSAR section revisions are being tracked by the WBN corrective action program. No additional licensing actions or exemption requests are needed to support the resolution of the emergency sump strainer blockage issues with the exception of RAI 9 above.

GL 2004-02 Request for Additional Information Response Source Documents

1. WCAP-16783-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and 3M® Fire Barrier Insulation for Watts Bar Nuclear Plant."

2. ALION-CAL-TVA-2739-03, "Watts Bar Reactor Building GSI-191 Debris Generation Calculation", Revisions 1, 3 and 4
   ALION-CAL-TVA-2739-04, "Watts Bar Reactor Building GSI-191 Debris Transport Calculation", Revision 1
   WAT-D-11530, "Containment Latent Debris Walkdown"
   51-9008451-002, "Test Report for SURE-FLOW™ Strainer Performance Test for WBN Nuclear."
   51-9005676-003, "Test Plan for SURE-FLOW™ Strainer (PROTOTYPE) Headloss Evaluation for WBN 1 ECCS Containment Sump Strainer."
   http://vermiculite.org/properties.htm
   MSDS 10-8339-3 for Interam 3M-M20C mat.
   TDI-6010-05, Revision 5, "Clean Head Loss - TVA/WBN Nuclear Plant"
   TDI-6010-06, Revision 6, "Total Head Loss-TVA/ WBN Nuclear Plant"

3. 51-9008451-002, "Test Report for SURE-FLOW™ Strainer Performance Test for WBN Nuclear."
   51-9005676-003, "Test Plan for SURE-FLOW™ Strainer (PROTOTYPE) Headloss Evaluation for WBN 1 ECCS Containment Sump Strainer."
   NUREG/CR-6885, "Screen Penetration Test Report", Los Alamos National Laboratory Report LA-UR-04-5416
   CN-CSA-05-2, Revision 0, "Watts Bar GSI-191 Downstream Effects - Vessel Blockage Evaluation"
   CN-CSA-05-7, Revision 3, "Watts Bar Sump Debris Downstream Effects Evaluation for ECCS Equipment"
   CN-CSA-05-10, Revision 3, "Watts Bar Sump Debris Downstream Effects Evaluation for ECCS Valves"
   CN-CSA-05-14, Revision 3, "Watts Bar GSI 191 Down Stream Effect Debris Ingestion Evaluation"
   CN-CSA-05-36, Revision 2, "Watts Bar GSI-191 Downstream Effects Debris Fuel Evaluation

4. WBN Calculation WBNOSG4-071, Revision 17, "RWST and Containment RHR Sump Safety Limits, Analytical Limits and Setpoints"
   Drawing SFS-WB1-GA-00, Revision 7, "WBN Unit 1 Sure-Flow® Strainer General Arrangement"
   Drawing SFS-WB1-PA-7100, Revision 9, "WBN Unit 1 Sure-Flow® Strainer Module Assembly-6 Disk"
   Drawing 48N919, Revision G, "Miscellaneous Steel Sump Liner Sheet 3"

5. TDI-6010-05, Revision 5, "Clean Head Loss - TVA/WBN Nuclear Plant"

6. WBN Calculation WBNOSG4-071, Revision 17, "RWST and Containment RHR Sump Safety Limits, Analytical Limits and Setpoints"
   TDI-6010-06, Revision 6, "Total Head Loss-TVA/ WBN Nuclear Plant"
   WAT-D-11715, "RHR Pump NPSH Calculation Results"
   Calculation EPM-RCP-120291, Revision 4, "Containment Spray Pump Net Positive Suction Head (NPSH) Calculation"
   Drawing SFS-WB1-GA-00, Revision 7, "WBN Unit 1 Sure-Flow® Strainer General Arrangement"
   Drawing SFS-WB1-PA-7100, Revision 9, "WBN Unit 1 Sure-Flow® Strainer Module Assembly-6 Disk"

7. 51-9008451-002, "Test Report for SURE-FLOW™ Strainer Performance Test for WBN Nuclear."
   51-9005676-003, "Test Plan for SURE-FLOW™ Strainer (PROTOTYPE) Headloss Evaluation for WBN 1 ECCS Containment Sump Strainer."

8. Calculation WBNOSG4-071, Revision 17, "RWST and Containment RHR Sump Safety Limits, Analytical Limits and Setpoints"
   ALION-REP-TVA-2739-02, Revision 0, "Watts Bar Unit 1: Characterization of Events That May Lead to ECCS Sump Recirculation"

Attachment 1 to Enclosure 2
Corrections to WBN's Supplemental Response to GL 2004-02

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 for only the four most limiting locations.

TVA Response
As a result of refined assumptions for 3M-M20C fire barrier insulation, the debris generation analysis, ALION-CAL-TVA-2739-03, Revision 4, "WBN Reactor Building GSI-191 Debris Generation Calculation (provided as Attachment 2 to Enclosure 2), revised results are presented as follows:

Debris Source Term for a Loop 1 Crossover Leg Break

Debris Type	Fines	Large Pieces/Chips	Total
3M-M20C (Interam) Fiber	33.4 ft^3	0 ft^3	33.4 ft^3
3M-M20C (Interam) Particulate	149 lb	0 lb	149 lb

Debris Source Term for a Loop 2 Crossover Leg Break

Debris Type	Fines	Large Pieces/Chips	Total
3M-M20C (Interam) Fiber	48.1 ft^3	0 ft^3	48.1 ft^3
3M-M20C (Interam) Particulate	214 lb	0 lb	214 lb

Debris Source Term for a Loop 3 Crossover Leg Break

Debris Type	Fines	Large Pieces/Chips	Total
3M-M20C (Interam) Fiber	9.50 ft^3	0 ft^3	9.50 ft^3
3M-M20C (Interam) Particulate	42.3 lb	0 lb	42.3 lb

Debris Source Term for a Loop 4 Crossover Leg Break

Debris Type	Fines	Large Pieces/Chips	Total
3M-M20C (Interam) Fiber	9.50 ft^3	0 ft^3	9.50 ft^3
3M-M20C (Interam) Particulate	42.3 lb	0 lb	42.3 lb

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

TVA Response
As a result of refined assumptions for 3M-M20C fire barrier insulation, it is assumed that the 3M material fails as 35% LDFG equivalent individual fibers at 7 micron and 65% at 10 micron particulate.

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

TVA Response
As a result of refined assumptions for 3M-M20C fire barrier insulation, the bounding quantities of 3M-M20C have been revised to the following:

Debris Type	Debris Quantity	Debris Transport Fraction (DTF)	Quantity at Sump
Fiber			
3M-M20C Fiber [LDFG volume]	48.1 ft^3	1.0	48.1 ft^3
Coatings/Particulate			
3M-M20C Particulate	214 lb	1.0	214 lb

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 clean strainer head loss calculation, TDI-6010-5, Revision 5, has been corrected to address the cover plate plenum opening head loss. In revision 4 of this calculation, a 10% margin had been added to the results. This unnecessary conservatism was removed during revision 5. As a result, the clean strainer head loss summary has been revised to the following:

WBN Clean Containment Sump Strainer Head Loss Summary

Head Loss Parameter	WBN "Long" Strainer Type "A"	WBN "Short" Strainer Type "B"
Strainer Assembly		
Uncorrected Clean Strainer Test	0.071 ft	0.050 ft
6% Test Uncertainty Correction	0.004 ft	0.003 ft
Flow, Perforated Plate	0.000 ft	0.000 ft
Strainer Length	0.000 ft	0.000 ft
Discharge Flow Plenum		
Strainer Discharge to Plenum	3.34 ft	3.34 ft
Plenum	0.0063 ft	0.0063 ft
Water Entering Sump Pit	0.195 ft	0.195 ft
Disk		
Disk Internal Flow Resistance	0.000 ft	0.000 ft
Total Strainer Head Loss	**3.62 ft**	**3.59 ft**

Based on these results, the limiting clean strainer head loss value has been revised to 3.62 ft for the WBN 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

As a result of the revised clean strainer head loss value, the debris laden strainer head loss results have also been revised and are as follows.

WBN Debris Laden Containment Sump Strainer Head Loss Summary

Head Loss Parameter	WBN "Long" Strainer Type "A"	WBN "Short" Strainer Type "B"
Clean Strainer Head Loss	3.62 ft	3.59 ft
Strainer Debris Laden Head Loss (Tested) with Temperature Correction for Post-LOCA Temperatures Applied	0.031 ft	0.031 ft
Total Strainer Head Loss	**3.65 ft**	**3.62 ft**

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

TVA Response

As a result of the revised clean strainer head loss value, the available excess NPSH for WBN sump recirculation operation has been recalculated. The minimum sump water level above the floor was revised from floor level to 5.48 ft - the most limiting value for a SBLOCA. The original analyses supporting the FSAR demonstrate that adequate NPSH margin exists for the emergency core cooling and containment spray systems. The most limiting case is used for NPSH margin:

Excess NPSH for Containment Sump Recirculation Operation at RHR Switchover:

RHR system	7.6 ft
CS system	5.5 ft

The updated NPSH calculation provided in TVA's Supplemental Response to GL 2004-02 (ADAMS Accession No. ML081090500) will be revised to include the revised clean strainer head loss value. This calculation revision is being tracked by the WBN corrective action program. This calculation includes more realistic assumptions to determine a better estimate of available margin (excluding the revised clean strainer head loss value). Given the more realistic assumptions, this calculation is expected to demonstrate even greater margin than the values given above.