TVA

Tennessee Valley Authority, Post Office Box 2000, Soddy-Daisy, Tennessee 37384-2000

February 29, 2008

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 Nos. 50-327
Tennessee Valley Authority (TVA)	)	50-328

SEQUOYAH NUCLEAR PLANT (SQN) UNITS 1 AND 2 - 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 NOS. MC4717, MC4718)

References:

1) TVA letter to NRC dated September 1, 2005, "Sequoyah Nuclear Plant (SQN) Units 1 and 2 - 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) – Second Response (TAC Nos. MC4717, MC4718)"

2) TVA letter to NRC dated December 21, 2006, "Sequoyah Nuclear Plant (SQN) Units 1 and 2 - 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) – Supplemental Response (TAC Nos. MC4717, MC4718)"

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

4) TVA letter to NRC dated November 28, 2007, "Sequoyah Nuclear Plant (SQN) Units 1 and 2 - 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 Nos. MC4717, MC4718)"

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NRR

In Reference 4, TVA notified NRC of the completion of the planned activities discussed in SQN's supplemental response to GL 2004-02 (Reference 2). Specifically, SQN has completed the design and installation of the sump strainers for the containment as committed in Reference 1.

The purpose of this letter is to provide the remaining information to support NRC verification that the completed corrective actions to address GL 2004-02 for SQN are adequate. This response was prepared using the guidelines set forth in Reference 3.

There are no new commitments made in this letter. If you have any questions concerning this matter, please contact me at (423) 843-7170.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 29th day of February 2008.

Sincerely,

James D. Smith
Manager, Site Licensing and
Industry Affairs

Enclosure
cc (Enclosure):

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ENCLOSURE
GL 2004-02 Supplemental Response

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 are in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of Generic Letter (GL) 2004-02 for debris loading conditions. 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 as follows.

Containment Walkdowns
Containment walkdowns were performed at both Sequoyah units to support the analysis of debris blockage as identified in the GL. The walkdowns were performed by personnel from Enercon, Westinghouse Electric Corporation (WEC), Alion Science and Technology, and Transco in consultation with TVA personnel using the guidelines provided in Nuclear Energy Institute (NEI) 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1.

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 Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology."

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.

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."

Chemical Effects Evaluation
A comparison of the NRC industry integrated chemical effects test program Test 5 and the Unit 1 & 2 plant specific parameters has been performed. The evaluation concluded that the critical

parameters in the integrated chemical effects test program Test 5 bound the plant parameters. To account for chemical effects, margin was added to the strainer head loss calculation.

Based on the results of the debris generation and transport analyses, the original containment sump intake screens were replaced with an advanced design containment sump strainer arrangement. 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 51 ft^2 to approximately 1609 ft^2. Scale testing of the advanced design strainer design confirmed the acceptability of the strainer arrangement to support ECCS and CSS operation for the design basis debris load with significant margins to accommodate beyond design basis debris loads.

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). (Note: All requests for extension should be submitted to the NRC as soon as the need becomes clear, preferably not later than October 1, 2007.)

> *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 were modified to include advanced designed strainers during the Unit 1, Cycle 15 refueling outage in the fall of 2007 and the Unit 2, Cycle 14 refueling outage in the fall of 2006. As discussed in the TVA letter to NRC dated November 28, 2007, installation of the strainers represents the only corrective action required to comply with the requirements of GL 2004-002. All actions related to the strainer installation were completed prior to December 31, 2007.

3. Specific Information Regarding Methodology for Demonstrating Compliance:

a. Break Selection

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

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

TVA Response

The following break locations were analyzed for Sequoyah:

- 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.

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 require ECCS recirculation, the size of the pipe break, and the proximity of other insulated pipes or equipment. Secondary line breaks were not considered in the evaluation because they do not require operation of the ECCS or CSS in the containment sump recirculation operating mode for accident mitigation or recovery.

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). Based on the large ZOIs, it does not matter where in any given loop that a break is taken. The confines of a single RCS loop are within the smallest ZOI and the projections of the debris generation sphere would be the same for any pipe in that loop.

Break 2 - Two or More Types of Debris

The only debris types within the crane wall are reflective metal insulation (RMI) and various coatings.

Break 3 - Most Direct Path to the Sump

Since the ECCS recirculation sump is next to the crossover leg in Loop 4, a break in this pipe would have a direct path to the sump.

Break 4 - Largest Particulate to Insulation Ratio

Only RMI is located within the polar crane wall in lower containment. RMI does not transport as easily as particulate and is not a major factor in developing headloss. As the quantity of RMI is not significant, the bounding case for each loop is which break would destroy the most coatings. By analyzing coating ZOIs at various locations on the primary loop piping, it was determined that a break in the crossover leg near the steam generator nozzle yields the most coating debris in any given RCS loop.

Break 5 - Potential Formation of the Thin-Bed Effect

This scenario addresses the generation of a small quantity of fibrous debris that, after 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. Based on walkdowns performed of containment buildings, Sequoyah has no fibrous insulation with the potential to be introduced in the post-accident recirculation inventory. However it could be postulated that latent fiber would be transported to the sump followed by the washdown of latent particulate debris, potentially resulting in the thin-bed effect. Based on the surface area of the advanced design containment sump strainers, there is insufficient fiber material in the latent debris to form a thin bed.

Based on these results, 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 postulated break in Loop 1 generates the most RMI debris and the postulated break in Loop 3 generates the most coatings particulate. Both of these breaks are in close proximity to the sump. The design basis debris load was conservatively established by combining the Loop 1 RMI debris load with the Loop 3 particulate load.

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.

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 Sequoyah were established using the NEI-04-07 methodology with no exceptions. Items not specifically addressed in the methodology were addressed consistent with the NRC Safety Evaluation Report (SER) issued for NEI-04-07.

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 Sequoyah containment was established as follows.

ZOI Radii for Sequoyah Debris Types

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

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

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 testing was conducted to determine the ZOIs used for Sequoyah debris generation calculations.

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	Unjacketed Large Pieces	Total
Stainless Steel RMI	98,822 ft^2 (75%)	32,940 ft^2 (25%)	131,762 ft^2
Debris Type	**Individual Fibers**	**Large Pieces**	**Total**
Latent Fiber	12.5 ft^3	0 ft^3	12.5 ft^3
Debris Type	**Particulate**	**Chips**	**Total**
Dirt/Dust	170 lb	0 lb	170 lb
IOZ Paint	1,752 lb	0 lb	1,752 lb
Phenolic Paint	36 lb	0 lb	36 lb
Silicone Paint	49 lb	0 lb	49 lb

Debris Type	Small Pieces	Unjacketed Large Pieces	Total
Alkyd Paint	5 lb	0 lb	5 lb
Carboline 295	256 lb	0 lb	256 lb

Debris Source Term for a Loop 2 Crossover Leg Break

Debris Type	Small Pieces	Unjacketed Large Pieces	Total
Stainless Steel RMI	90,157 ft^2 (75%)	30,052 ft^2 (25%)	120,209 ft^2
Debris Type	**Individual Fibers**	**Large Pieces**	**Total**
Latent Fiber	12.5 ft^3	0 ft^3	12.5 ft^3
Debris Type	**Particulate**	**Chips**	**Total**
Dirt/Dust	170 lb	0 lb	170 lb
IOZ Paint	1,752 lb	0 lb	1,752 lb
Phenolic Paint	37 lb	0 lb	37 lb
Silicone Paint	49 lb	0 lb	49 lb
Alkyd Paint	5 lb	0 lb	5 lb
Carboline 295	261 lb	0 lb	261 lb

Debris Source Term for a Loop 3 Crossover Leg Break

Debris Type	Small Pieces	Unjacketed Large Pieces	Total
Stainless Steel RMI	81,806 ft^2 (75%)	27,269 ft^2 (25%)	109,075 ft^2
Debris Type	**Individual Fibers**	**Large Pieces**	**Total**
Latent Fiber	12.5 ft^3	0 ft^3	12.5 ft^3
Debris Type	**Particulate**	**Chips**	**Total**
Dirt/Dust	170 lb	0 lb	170 lb
IOZ Paint	1,752 lb	0 lb	1,752 lb
Phenolic Paint	56 lb	0 lb	56 lb
Silicone Paint	48 lb	0 lb	48 lb
Alkyd Paint	5 lb	0 lb	5 lb
Carboline 295	392 lb	0 lb	392 lb

Debris Source Term for a Loop 4 Crossover Leg Break

Debris Type	Small Pieces	Unjacketed Large Pieces	Total
Stainless Steel RMI	76,943 ft^2 (75%)	25,647 ft^2 (25%)	102,590 ft^2
Debris Type	**Individual Fibers**	**Large Pieces**	**Total**
Latent Fiber	12.5 ft^3	0 ft^3	12.5 ft^3
Debris Type	**Particulate**	**Chips**	**Total**
Dirt/Dust	170 lb	0 lb	170 lb
IOZ Paint	1,752 lb	0 lb	1,752 lb
Phenolic Paint	56 lb	0 lb	56 lb
Silicone Paint	48 lb	0 lb	48 lb
Alkyd Paint	5 lb	0 lb	5 lb
Carboline 295	381 lb	0 lb	381 lb

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

TVA Response

Based on containment walkdown results, a conservative estimate of the total surface area of all signs, placards, tags, tape and similar miscellaneous materials in containment was established as 850 ft^2.

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 637.5 ft^2 surface area blockage.

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.

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 Sequoyah containment buildings are as follows.

Reflective Metal Insulation

Generic testing of the RMI used in the Sequoyah containment established that 71 percent of the 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 Sequoyah RMI debris.

Coatings

Essentially all steel surfaces at Sequoyah are coated with Carbozinc™ 11 (an inorganic zinc primer) and were left untopcoated. 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 up to 6 feet have been painted with two coats of Phenoline™ 305. All concrete below 6 feet has also been painted with a Carboline™ 295 surfacer. The steam generators and pressurizer are coated with Carboline™ 4674 underneath the RMI insulation. This coating is a high temperature silicone 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. A dry film bulk density of 87 lb/ft^3 was derived using published properties for Carboline™ 4674. This value was also assumed to be the density of the particulate.

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 Sequoyah analysis.

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 Sequoyah 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
Alkyd Paint (Fines)	98 lb/ft^3	98 lb/ft^3
IOZ Paint (Fines)	223 lb/ft^3	145 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)	-	168 lb/ft^3
Latent Fiber (Fines)	2.4 lb/ft^3	94 lb/ft^3

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

TVA Response

The specific surface area for fibrous and particulate debris (S_V) was only used for the analytical assessment of the debris laden head loss for the original Sequoyah sump intake screens. The head loss across the current advanced design containment sump strainers was established by test. As such, these values are not part of the current sump strainer design basis.

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 Sequoyah 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.

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.

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 Sequoyah containment building was based on the assumptions discussed in Item 3.d.2 below. A quantitative latent debris walkdown was performed on Sequoyah Unit 2 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 31 locations inside the containment building selected to provide a representative sample of the latent debris present in containment. The sample collection area for each location varied in size from 1 ft^2 to 70 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.

The results of the Sequoyah Unit 2 survey were extrapolated to apply to Sequoyah Unit 1 based on the observations of the survey staff and the common containment cleanliness practices applied to both units.

2. Provide the basis for assumptions used in the evaluation.

TVA Response

The assumptions concerning latent debris in the Sequoyah 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 was assumed to be 200 lb. Of the 200 lbs, 170 lb was assumed to be dirt/dust and the remaining 30 lb was assumed to be fiber.

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 found small quantities of particulate debris such as rust, paint, and dust. The quantity found projects to a total containment quantity of 24.5 pounds. Only a few latent fibers were found. The total quantity of fiber was considered to be insignificant. 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 Sequoyah containment buildings.

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 637.5 ft^2 has been established for latent debris in the form of signs, placards, tags, tape and similar miscellaneous materials.

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.

1. Describe the methodology used to analyze debris transport during the blow down, wash down, pool fill-up, and recirculation phases of an accident.

TVA Response

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

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

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

The detailed methodology used for the Sequoyah transport analysis is as follows.

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

b. 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.

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

d. The fraction of debris blown into the ice condenser was determined based on the flow of steam during the blow down.

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

f. 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.

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

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

i 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.

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

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

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

This 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.

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. 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 Sequoyah 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.

a. The mesh in the CFD model was nodalized to sufficiently resolve the features of the CAD model discussed in the response to Item 3.e.1 above.

b. The boundary conditions for the CFD model were set based on the configuration of Sequoyah during the recirculation phase.

c. 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.

d. 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.

e. 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.

f. An appropriate turbulence model was selected for the CFD calculations.

g. 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.

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

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

a. 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 the larger recirculation transport fractions determined from the Loop 2 and Loop 4 CFD simulations can be applied to the Loop 1 and Loop 4 breaks. In general, breaks close to the sump transport a larger fraction of large piece debris, and breaks farther from the sump transport a larger fraction of fine debris. Therefore, since Loop 2 is farthest from the sump and Loop 4 is closest to the sump, applying the larger fine debris transport fraction from Loop 2 and the larger RMI transport fraction from Loop 4 is considered conservative for the other two break locations.

b. 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.

c. 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. Sensitivity studies performed which introduce the drainage at the surface of the pool have confirmed that this assumption is conservative.

d. 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 120 gallons per minute (gpm) through Room 3 and Room 4). Therefore, all of the spray water was introduced through the refueling canal drains.

The recirculation debris transport fractions were determined from the CFD simulations performed for a break in the 31" inner diameter crossover leg at the base of the steam generator for each of the primary system loops. As described above, the recirculation 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.

Recirculation Transport Fractions of Debris to Sump Screen (Loops 1, 3 and 4 - Bounds Loop 2)

Debris Type	Fines	Small Pieces	Large Pieces
Stainless Steel RMI	NA	51%	51%
Phenolic Paint (inside ZOI)	100%	NA	NA
Epoxy Paint (inside 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

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 Sequoyah debris transport analysis.

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

TVA Response

Fine debris was not assumed to settle in the Sequoyah debris transport analysis.

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	131,762 ft^2	0.51	67,199 ft^2
Coatings			
Phenolic	56 lb	1.0	56 lb
IOZ	1,752 lb	1.0	1,752 lb
Alkyds	5 lb	1.0	5 lb
Silicone	49 lb	1.0	49 lb
Carboline 295	392 lb	1.0	392 lb
Latent Debris			
Latent Fiber(2)	12.5 ft^3	1.0	12.5 ft^3
Dust & Dirt	170 lb	1.0	170 lbm
Tags and Tape(1)	850 ft^2	1.0	850 ft^2

(1) 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.

(2) 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 12.5 ft^3 (30 lb/2.4 lb/ft^3).

The most limiting amount of RMI calculated to be available at the sump resulted from the Loop 1 break. The most limiting amount of coatings at the sump resulted from the Loop 3 break. The bounding coating load from Loop 3 was applied to the bounding RMI load from Loop 1 to establish the bounding amount of debris at the sump summarized above.

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.

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

TVA Response

Schematic flow diagrams of the Sequoyah ECCS and CSS are contained in the Sequoyah Updated Final Safety Analysis Report (UFSAR). Refer to Figure 6.2.2-1 for the CSS and Figure 6.3.2-1 for the ECCS.

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 Sequoyah containment sump strainer under LBLOCA and SBLOCA conditions occurs at the time of initial recirculation operation. Minimum submergence values are as follows.

Containment Sump Strainer Minimum Submergence

Conditions	**Minimum Sump Level**	**Strainer Assembly Height**	**Minimum Submergence**
Large Break LOCA			
ECCS Recirculation	9.06 ft	(1)Short - 2.6 ft	6.46 ft
	9.06 ft	(1)Tall 7.4 ft	1.66 ft
CSS Recirculation	13.22 ft	Short - 2.6 ft	10.62 ft
	13.22 ft	Tall 7.4 ft	5.82 ft
Small Break LOCA			
ECCS Recirculation	5.04 ft	Short - 2.6 ft	2.44 ft
	5.04 ft	Tall 7.4 ft	Partially Submerged
CSS Recirculation	6.09 ft	Short - 2.6 ft	3.49 ft
	6.09 ft	Tall 7.4 ft	Partially Submerged

(1) Sequoyah strainers are of different heights as discussed in Item 3.j.1 below.

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

TVA Response

The original Sequoyah containment sump intake structure contained a number of design features (i.e., grating, baffle plates, and screens) which 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. The effect of the modification was to distribute the inlet flow such the approach velocities to the sump entrance were reduced. As none of the other vortex suppression features shown in Sequoyah UFSAR Figure 6.3.2-4 were altered by the modification, the effect of the change was qualitatively determined to decrease the potential for vortex formation such that the original scale testing remains valid.

The potential for vortex formation in the strainer central flow channels was also evaluated. All of the Sequoyah 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 0.095" diameter holes. Based on this configuration, the largest opening for water into the strainer flow channel is through the 0.095" diameter holes. The size of the plate openings will prevent formation of a vortex when fully submerged. The openings are sufficiently small that any air column formed by a vortex is collapsed by the surrounding water. If a number of "mini-vortices" were to form and combine in the interior of the disks, the combination of the wire stiffener "sandwich" and the small openings and passages that direct flow to the strainer central flow channel would preclude the formation of a vortex in either the flow channel or the sump structure.

For a SBLOCA, not all of the Sequoyah sump strainers will be fully submerged at the initiation of sump recirculation operation. While the "short" strainer stacks will be fully submerged, the "tall" strainer stacks will only be partially submerged. To address the potential for sump vortexing under these conditions, standard hydraulic principals and equations were used to establish the minimum sump level required to ensure that the strainer central flow channel level does not drop below the top of the strainer discharge plenum for the maximum combined ECCS and CSS flow rates. This minimum required level was then compared to the established minimum sump level for SBLOCA recirculation operation. A minimum SBLOCA sump level which exceeds the minimum level required to keep the water level in the "tall" strainer flow channels above the top of the discharge plenum will preclude vortex formation in the sump. The results of these evaluations confirmed that the minimum sump level for SBLOCA recirculation was sufficiently high to maintain the water level in the "tall" strainer flow channels above the top of the discharge plenum. Thus, vortexing in the sump will not occur for SBLOCA recirculation operation.

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.

<u>TVA Response</u>

Testing of the advanced design containment sump suction strainers 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 Sequoyah (i.e., the strainer surface area and maximum strainer opening size) and the existing plant ECCS flow requirements.

The testing was 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 Sequoyah design basis ECCS volumetric flow rate. The debris quantity for the strainer test was in proportion to the scaled flow through the test module.

The following debris loading conditions were included in the 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 Sequoyah 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 Sequoyah 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 Sequoyah 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 will 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 0.095" diameter 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 by an order of magnitude (i.e., by a factor of 10). 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 - Maximum Latent Debris (Fiber) Test

This test measured the performance of the containment sump strainers for a maximum latent debris load case. The debris load is the same as for the design basis test with the following exceptions. The quantity of latent dust and dirt was increased by an order of magnitude. The size of the failed coatings was revised to reflect a spectrum of chip sizes similar to the maximum coating inventory test with the exception of the IOZ coatings. Based on industry testing, the IOZ coatings will fail as particulate. Additional debris to address containment sump chemical effects was also added similar to the maximum coating inventory case. The quantities of latent debris fiber will be same as for the design basis test. The amount of assumed fiber in the design basis test is more than an order of magnitude larger than the actual containment fiber content and remains conservative. This test will establish beyond design basis strainer performance for quantities of latent debris. It was intended to demonstrate sufficient strainer operational margin to preclude the need for a specific latent debris operational limit. It also established operational margins to address potential strainer blockage due to chemical effects.

Test 5 - Maximum Latent Debris (Fiber) Sensitivity Test

This test was performed as a variation of Test 4. The debris load and test conditions were identical with the exception that the fiber load was increased by an order of magnitude to establish the sensitivity of the strainer design to increased fiber loads.

Test 6 - Near Field Effects Sensitivity Test

This test was performed as a variation of Test 3. The debris load and test conditions were identical with the exception that all of the debris was placed on or in the immediate vicinity of the test strainer at the start of the test. This test was performed to confirm that potential "near field flow effects" associated with the testing configuration (which has the potential to alter the debris transport characteristics) do not a have a significant effect on the measured strainer head loss.

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)	Velocity Head Loss (ft)	Debris Load Head Loss (ft)	Total Measured Head Loss (ft)	Average Water Temperature (°F)
1	0.0166	0.0162	0.014	0.047	53.7
2	0.0166	0.0162	0.010	0.043	53.3
3	0.0166	0.0162	0.017	0.050	46.3
4	0.0166	0.0162	0.007	0.040	51.5
5	0.0166	0.0162	0.033	0.066	53.9
6	0.0166	0.0162	0.045	0.078	46.3

Based on these results, the total measured head loss for the test summarized in Test 6 was selected as the limiting debris head loss.

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 Sequoyah 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.

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

TVA Response

The Sequoyah 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, the only source of fibrous material debris available for transport to the containment sump is the assumed maximum amount of fiber for latent debris. This results in a very high particulate to fiber ratio such that the debris bed porosity for Sequoyah is essentially that of the particulate mix. Since Sequoyah plant conditions are such that a thin bed can be precluded (i.e., very little fiber, a deep water pool, with debris predominantly in the form of fines), the analysis of thin bed effects was performed primarily to establish a minimum flow area criterion for the prevention of thin bed formation. The minimum advanced design strainer surface area required to prevent formation of a uniform thin fiber bed was established at 420 ft^2 for the Sequoyah sump recirculation operating conditions. The final sump strainer flow area (1609 ft^2) significantly exceeds the minimum requirement such that thin bed effect head losses are not expected to occur.

To confirm this design objective, a series of flow transport/blockage tests was 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. 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); 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); and 3) the maximum latent debris inventory (i.e., the quantity of assumed latent dust and dirt was increased by an order of magnitude to bound latent debris effects). In all cases, thin bed formation did not occur.

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 Sequoyah ECCS and CSS service conditions. The limiting measured debris head loss was established by test and was adjusted for dynamic viscosity differences between the test temperature and the expected post-accident sump temperature. Additionally, this debris blockage head loss was increased by 10 percent to establish margin for potential sump inventory chemical effects. The strainer design maximum head loss was then established by adding the final adjusted debris blockage head loss value to the calculated clean strainer/flow plenum head loss value.

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

TVA Response

The significant conservatisms used in the Sequoyah head loss and vortexing calculations which establish strainer assembly design margins are as follows.

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

b. Clean strainer flow plenum head loss values calculated using standard hydraulic flow resistance equations were conservatively increased by 10 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) and a conservative debris transport technique (see Description of Test 6 in the response to Item 3.f.4 above).
e. An additional strainer head loss margin allocation of 10 percent was applied to the maximum debris head loss value to conservatively account for potential sump inventory chemical effects.
f. The ECCS and CSS flow values used in the vortexing calculations are based on pump design values without application of piping flow resistance losses.
g. A conservatively low containment sump level was used to perform the small break LOCA partial strainer submergence head loss/vortex evaluation described in the response to Item 3.f.3 above.

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

TVA Response

The Sequoyah 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 Sequoyah 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 Sequoyah 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 to the Sequoyah 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. Comparison of the Sequoyah strainer assemblies to the prototype test assembly found that the tested configuration bounded the Sequoyah configuration with the exception of the strainer core length dimension for the Sequoyah "tall" strainer assemblies (refer to Item 3.j.1 for a detailed description of the Sequoyah strainer assemblies). The active length of the Sequoyah "tall" strainers (approximately 67 inches long) exceeds the active length of the tested strainer (54 inches). Using a standard equation for head loss associated with incompressible flow in a pipe, a conservative head loss for the entire length of the "tall" strainer was established and conservatively added to head loss total (see the "Strainer Length Correction" in the table below).

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. Because the core tubes of the "A," "B," and "D" stack strainer assemblies are located directly over the sump entrance, this flow resistance was not applied to them.

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.

Sequoyah Clean Containment Sump Strainer Head Loss Summary

Head Loss Parameter	**Sequoyah "Short" Strainer Assembly Stacks "A" and "B"**	**Sequoyah "Tall" Strainer Assembly Stacks "C" and "E"**	**Sequoyah "Tall" Strainer Assembly Stack "D"**
Strainer Assembly			
Clean Strainer Test	0.102 ft	0.617 ft	0.617 ft
Test Uncertainty Correction	0.006 ft	0.037 ft	0.037 ft
Strainer Length Correction	0.000 ft	0.012 ft	0.012 ft
Discharge Flow Plenum			
Strainer Discharge to Plenum	0.109 ft	0.727 ft	0.727 ft
Sump Pit Entrance Resistance	0.000 ft	0.543 ft	0.000 ft
Total Strainer Head Loss	**0.217 ft**	**1.936 ft**	**1.393 ft**

Based on these results, a limiting clean strainer head loss value of 1.94 ft was established for the Sequoyah strainer assemblies.

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

TVA Response

The Sequoyah 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 are as follows.

Sequoyah Debris Laden Containment Sump Strainer Head Loss Summary

Head Loss Parameter	**Sequoyah "Short" Strainer Assembly**	**Sequoyah "Tall" Strainer Assembly**
Clean Strainer Head Loss	0.217 ft	1.94 ft
Strainer Debris Laden Head Loss (Tested) with Temperature Correction for Post-LOCA Temperatures Applied	0.028 ft	0.028 ft
Total Strainer Head Loss	**0.245 ft**	**1.97 ft**

Based on these results, a limiting debris laden head loss value of 1.97 ft was established for the Sequoyah strainer assemblies.

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

As discussed in the response to Item 3.f.2, the Sequoyah advanced design containment sump strainers are fully submerged upon initiation of containment sump recirculation operations for a large break LOCA. All of the sump strainers are not fully submerged for ECCS recirculation for a small break LOCA. In addition to the NPSH margin evaluation, a votexing/air intrusion evaluation was also performed for the small break LOCA configuration. As discussed in the response to Item 3.f.3, the evaluation confirmed that sump vortexing and significant air intrusion do not occur for this operating configuration.

12. State whether near-field settling was credited for the head-loss testing and, if so, provide 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 Sequoyah. As discussed in response to Item 3.f.4, a specific test was performed (Test 6) 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.

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 Sequoyah, 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 Sequoyah advanced design strainers (i.e., 0.0260 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 (133°F) to the colder test water temperature (46°F) 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 Sequoyah 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.

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.

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.

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 Sequoyah sump recirculation NPSH calculation are as follows.

Sequoyah ECCS and CSS Flows Rates for Sump Recirculation NPSH Calculation

	Large Break LOCA	Small Break LOCA
Unit 1 CSS	5169 gpm	5169 gpm
Unit 1 ECCS (Residual Heat Removal)	5500 gpm	2460 gpm
Total Recirculation Flow (Unit 1)	**10,669 gpm**	**7,629 gpm**
Unit 2 CSS	5068 gpm	5068 gpm
Unit 2 ECCS (Residual Heat Removal)	5500 gpm	2460 gpm
Total Recirculation Flow (Unit 2)	**10,568 gpm**	**7,528 gpm**

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

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

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:

a. The residual heat removal (RHR) pumps in each train were established as operating at the design maximum flow to maximize ECCS flow for a large break LOCA.
b. For a small break LOCA, primary system pressures may remain sufficiently high to prevent RHR flow to the primary system. For these cases, maximum RHR flow was established as the total run-out flow of both trains of safety injection pumps(intermediate head) and centrifugal charging pumps(high head).
c. Flow through each train of the CSS was calculated using inputs which maximize the flow. These inputs include:
    - The highest level in the containment sump was used in conjunction with nominally low RHR flows. These inputs 1) maximize the CSS suction head, and 2) minimize the piping resistance pressure loss though the common ECCS and CSS suction piping.
    - The pressure in upper containment was modeled as 0.0 psig to establish the least resistance to flow through the CSS spray nozzles.
    - Each CSS heat exchanger was modeled with no tube plugging allowance to minimize the flow resistance across the heat exchangers

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. 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 Sequoyah 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.

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. The analytical model was constructed for the Sequoyah plant specific piping configuration using the MULTIFLOW, Version 1.21 computer code. 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.

5. Describe the system response scenarios for LBLOCA and SBLOCAs, and

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

TVA Response

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 RWST 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 reaching the 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 sum,p 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, a portion of one train of RHR pump flow to the primary system cold legs is directed to the containment RHR spray headers. 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 cold 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. At this point, the SIP pumps are realigned by manual operator action to inject to the primary system hot legs rather than the cold legs. The RHR and 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 will likely 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.

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 Sequoyah (i.e., large break LOCA and small break LOCA) is the complete loss of one train of ECCS equipment.

8. Describe how the containment sump water level is determined.

TVA Response

The containment sump water level is established by comparison of the lower containment volumes which are available to collect water for recirculation to the minimum volume of water discharged during the event. The minimum discharge volume does not include the volume which is unavailable to the sump/lower containment.

The sump and lower containment volumes available to collect recirculation inventory were 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/pressurizer enclosure, 3) water in the upper containment atmosphere, 4) water held up in the accumulator rooms, and 5) water in the containment spray piping.

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

a. 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.

b. 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.

c. 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.

d. Vortex suppression devices (normal operating covers) will be in place in each of the refueling canal drains whenever the plant is in operation. This assumption has the effect of increasing the amount of water unavailable to the sump which is conservative for the sump level calculation.

e. Flow into the reactor cavity through the neutron monitor windows is negligible.

f. A 3 percent 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. For the lower containment, the major and miscellaneous equipment volume occupies approximately 4 percent of the total volume. From the perspective of the current calculation's purpose, it is conservative to have a smaller equipment volume, thereby reducing water level.

g. 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

h. The small break LOCA must be evaluated for two possible scenarios regarding minimum containment sump elevations. These scenarios are: 1) a break which is sufficiently small to not activate the containment spray, and 2) a break which is sufficiently large to activate the containment spray system. Consideration of both scenarios will ensure that the minimum level is calculated.

i. No 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.

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

k. 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.

l. Because of the small break size possible, no credit is taken for primary system inventory discharge.

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

TVA Response

The volumes for empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces have been accounted for in the Sequoyah 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 and this volume was subtracted from the sump discharge volume.

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. The volume of water suspended between the spray header exit and the operating deck/ refueling canal was subtracted from the sump discharge volume.

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. This consideration was taken independent of the break location.
- Operating Deck/Pressurizer Enclosure - Water will accumulate on the operating deck 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 water accumulation on the operating deck/pressurizer enclosure roof 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 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 level of water suspended in the accumulator rooms was calculated for equilibrium conditions as function of 1) drain flow resistance, 2) floor drain level (i.e., driving head though the drains) and 3) air return fan inventory deposit rate . The volume of water suspended in the accumulator rooms was established from the equilibrium level of water held up in the rooms.

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. The calculated equipment volume was found to be approximately 4 percent of the total lower containment volume.

Based on this result, a 3 percent reduction in the lower containment volume was conservatively applied to the to the sump level calculation to account for equipment and structures in the lower containment. This allowance is not used for the sump pocket, the refueling canal or the reactor cavity since they do not contain equipment.

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 Sequoyah minimum containment sump level calculation were established as follows.

a. 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, no credit is taken for the primary system inventory.

b. 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 a small break LOCA, no credit is taken for the volume of the accumulators.

c. 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.

d. 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, no 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.

Sequoyah Sump Recirculation Pool Source Inventory Summary

	Large Break LOCA	**Small Break LOCA**
Primary System Inventory	68,008 gallons	0 gallons
Cold Leg Accumulator Inventory	30,460 gallons	0 gallons
RWST Inventory	196,241 gallons	196,241 gallons
Ice Melt Inventory	131,662 gallons	0 gallons
Total	**426,321 gallons**	**196,241 gallons**

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 Sequoyah.

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

TVA Response

The Sequoyah containment sump operation 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.

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

TVA Response

The Sequoyah 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., 9.43 psia for a temperature of 190°F).

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

TVA Response

The available excess NPSH for Sequoyah sump recirculation operation is as follows.

Sequoyah Excess NPSH for Containment Sump Recirculation Operation

Pump	Large Break LOCA Excess NPSH	Small Break LOCA Excess NPSH
Unit 1-A RHR Pump	6.7 ft	25.5 ft
Unit 1-B RHR Pump	7.7 ft	25.9 ft
Unit 1-A CSS Pump	15.4 ft	14.6 ft
Unit 1-B CSS Pump	14.4 ft	13.2 ft
Unit 2-A RHR Pump	6.9 ft	25.7 ft
Unit 2-B RHR Pump	7.8 ft	26.0 ft
Unit 2-A CSS Pump	15.9 ft	15.1 ft
Unit 2-B CSS Pump	14.9 ft	13.7 ft

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.

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.

<u>TVA Response</u>

Based on design and containment walkdown data, essentially all steel surfaces at Sequoyah are coated with Carbozinc™ 11 (an inorganic zinc primer) and were left untopcoated. The containment liner is also coated with Carbozinc™ 11 and has been left without a topcoat. The concrete floors and walls up to 6 feet have been painted with two coats of Phenoline™ 305. All concrete below 6 feet has also been painted with a Carboline™ 295 surfacer. The steam generators and pressurizer are coated with Carboline™ 4674 underneath the RMI insulation.

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

<u>TVA Response</u>

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

General Assumptions

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

b. 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).

c. 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

d. 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.

e. 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.

f. 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.

g. 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

h. 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.

i. The unqualified coatings in upper containment were assumed to be in the location of the refueling canal drain lines at the beginning of recirculation. This is a conservative assumption since the two drain lines discharge near the sump strainer.

j. 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.

k. 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.

l. It was assumed that small and large piece debris would be uniformly distributed between the locations where it is destroyed and the 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. 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.

TVA Response

The Sequoyah 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:

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

4. Provide bases for the choice of surrogates.

TVA Response

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

- Silicon Carbide - The actual phenolic, alkyd, and silicone coatings used inside the Sequoyah 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 Sequoyah 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.

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 Sequoyah was established based on the following methods/assumptions.

a. A containment walkdown was performed to identify and locate coatings in lower containment.
b. Pipe break locations were selected based on the accident scenarios that could lead to containment sump recirculation operation.
c. An affected coating ZOI was established from an assumed equivalent spherical ZOI radii to pipe break diameter ratio (r/D) of 10.0.

d. 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.
e. 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 Sequoyah coating debris generation analysis are consistent with NEI-04-07 and the associated the NRC SER.

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 Sequoyah are consistent with NEI-04-07 and the associated NRC SER (as well as applicable test data).

7. Describe any ongoing containment coating condition assessment program.

TVA Response

The current TVA protective coating program contains requirements for conducting periodic visual examinations of all accessible Coating Service Level I and Level II corrosive environment protective coatings. The inspections are 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 are performed by qualified personnel according to established inspection plans and acceptance criteria. Any coating defects identified as part of the periodic inspection are 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.

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 Sequoyah 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.

The following is a summary of the procedures and engineering specifications which constitute the present containment material control and inspection requirements at Sequoyah that pertain to ensuring operability of the containment sump.

a. Surveillance Instruction 0-SI-SIN-063-009.0, "Sump Pit Inspection" - A procedure that provides detailed steps for the inspection of the RHR/containment sump. A visual inspection of the RHR/containment sump is performed once every 18 months in order to verify the suction valve inlets are not restricted by debris.

b. Surveillance Instruction 0-SI-SXX-061-001.0, "Ice Condenser Loose Debris Evaluation" - A procedure that describes the evaluation and approval process for loose debris in the ice condenser.

c. Technical Instruction 0-TI-SXX-061-001.0, "Ice Condenser Loose Debris Listing" - Documents and maintains a record of the debris in the ice condenser that has been assessed by O-SI-SXX-061-001.0.

d. 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.

e. 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.

f. 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.

g. 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.

h. Surveillance Instruction 0-SI-OPS-000-011.0, "Containment Access Control - Modes 1-4" - This surveillance 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.

i. Surveillance Instruction 0-SI-OPS-000-187.0, "Containment Inspection" - This surveillance instruction provides the overall containment close-out prior to entry into Mode 4 during startup, including demonstrating good housekeeping in containment by ensuring no loose debris ors present which could be transported to the containment sump and cause restriction to RHR and CSS pump suction.

j. 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.

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

l. Technical Instruction 0-TI-DXX-000-010.0, "Protective Coatings Program for Coating Service Level I and II and Corrosive Environmental Applications" - This technical instruction establishes organizational responsibilities and department interfaces required for implementation of the protective coating program at SQN, including requirements associated with controlling and tracking the inventory of unqualified coatings installed inside primary containment that could adversely impact containment sump operability.

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.

Additionally, design and operational refinements suggested by NEI-04-07 (Section 5) and the associated NRC SER (Section 5.1) were reviewed relative to the advanced design containment sump strainer modification at Sequoyah. Based on the operating margins provided by the advanced design sump strainers for the present debris load, no replacement or modification (e.g., jacketing or banding) of insulation in containment was required to reduce the debris burden on the strainers. Similarly, no changes to the containment coatings program were required to remove or replace coatings inside containment.

j. Screen Modification Package

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

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

TVA Response

The Sequoyah 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 0.095" diameter flow openings. After passing through the strainer skin, intake flow is directed to a central flow channel. The strainer disks are stacked on top of each other to from strainer modules (See Figures 3.j.1-1 and 3.j.1-2, copies attached).

The Sequoyah strainer assembly is made up of two stacks of a 7-disk strainer module and three stacks of 6-disk strainer modules. The 7-disk module stacks consist of only one module each. The 6-disk module stacks consist of six modules each. The strainer stacks are bolted onto a flow plenum which directs the flow to the sump intake (see Figure 3.j.1-3, copy attached). The total flow area of the Sequoyah advanced design containment sump strainer assembly is 1609 ft^2.

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

With the exception of the demolition of the original flat plate sump intake screens and the minor rerouting of small bore piping and electrical conduit to establish the required clearances, no other modifications were required to support installation of the advanced design sump strainers.

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.*

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 Sequoyah 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 Sequoyah sump strainers and plenum assembly consisted of the following.

a. Strainer/plenum arrangement and dimensional data from the appropriate component design and fabrication drawings.
b. Strainer/plenum material types from the appropriate component design and fabrication drawings.
c. Design and maximum operating temperatures from the strainer/plenum design specification.
d. Sequoyah plant specific seismic acceleration response spectra from the strainer/plenum design specification.
e. Structural analysis load types, combinations and acceptance criteria from the strainer/plenum design specification.

Design Codes

The Sequoyah 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.

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

The primary design and fabrication standard for the Sequoyah 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 were 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 were also based on this code. In addition, the AISC Code does not specifically cover stainless steel materials. Since the strainers were 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) were used from the ASME Code. Load combinations and allowable stress factors for higher service level loads were 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.

a. DW - Strainer and support dead weight loads and forces.
b. TOL - Thermal effect loads during normal operation (loads imposed by a conservatively assumed maximum normal operating temperature of 140°F)
c. OBE - Seismic loads generated by the operating basis earthquake
d. SSE - Seismic loads generated by the safe shutdown earthquake
e. TAL - Thermal effect loads during accident operation (loads imposed by the maximum accident operating temperature of 190°F)
f. JIL - Jet impingement equivalent static load (if applicable) - Note c
g. DIL - Debris impact equivalent static load
h. DP - Differential pressure across perforated plates and other pressure boundaries - Note d
i. DEB - Debris Weight - Note e

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

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

Notes

a. 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 were evaluated against the allowable loads for the selected anchor bolts in TVA Design Standard No. DS-C1.7.1 Revision 11.

b. 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
$0.9 \times F_{\text{critical buckling}}$	for Compression Stress

where Fy = minimum specified yield strength of the material, and
$F_{\text{critical buckling}}$ = the compressive stress calculated by the AISC equations without the appropriate factor of safety

c. The jet impingement load (JIL) and debris impact load (DIL) were negligible for the strainer design based on the strainer location.

d. The differential pressure (DP) was specified be the component design basis maximum 3.5 feet of water.

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

f. Hydrostatic or hydrodynamic loads were not included for the load combinations which include OBE and SSE loads. The plant design basis precludes submerged conditions for seismic events.

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

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

TVA Response

The 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.

Sequoyah 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)	0.88	Support Beams	0.11
Tension Rods	0.46	Support Floor Beam Local Web	0.65
Edge Channels	0.61	Top Cover Plate	0.61
Cross Bracing	0.34	Lower Deck Plate	0.18
Hex Coupling	0.38	Cross Beam Over Pit	0.32
Core Tube	0.15	Hex Couplings	0.92
Radial Stiffeners (Bent Portion)	0.35	Plenum Box Channels	0.18

Strainer Component	Maximum Stress Ratio	Flow Plenum Component	Maximum Stress Ratio
Spacer	0.87	Plenum Box Channel Local Web	0.05
Spacer Separation	0.82	Lower Deck Drainage Perforated Plate	0.78
Perforated Plate (DP Case)	0.24	Lower Deck Drainage Plate Openings	0.03
Perforated Plate (Seismic Case)	0.06	Strainer to Substructure Bolts	0.52
Perforated Plate (Inner Gap)	0.14	Channel to Support Beam Bolts	0.57
Inner Gap Buckling	0.27	Channel Local Flange at Bolts	0.95
Wire Stiffener	0.90	Bottom Plates to Beam Bolts	0.57
Perforated Plate (Core Tube End Cover DP Case)	0.60	Channel Splice Plate Bolts	0.26
Radial Stiffening Spokes of the End Cover Stiffener	0.72	Channel to Channel Splice Welds	0.06
End Cover Sleeve	0.50	Channel Splice Plate	0.15
Weld of Radial Stiffener to Core Tube	0.12	Cross Beam to Angle Bolts	0.21
Weld of End Cover Stiffener	0.41	Concrete Expansion Anchors	0.77
Edge Channel Rivets	0.07	Floor Beam Local Flange at Bolts	0.88
Inner Gap Hoop Rivets	0.04	Clip Angle to Sump Curb Weld	0.96
End Cover Rivets	0.00	Lug at Sump Curb	0.05
Connecting Bolts	0.35	Embedded Angle	0.98

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 Sequoyah containment sump strainers was reviewed relative to the existing containment pipe break dynamic effects analysis. 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 was consistent with current Sequoyah 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.

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

TVA Response

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

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).

> *GL 2004-02 Requested Information Item 2(d) CM*
> *The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.*

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.

TVA Response

Containment walkdowns were performed in accordance with the guidance of NEI 02-01. These walkdowns identified three potential choke-points which could prevent adequate water inventory from reaching the containment sump. The potential choke-points are the two 14" diameter refueling canal drains and a drain in Accumulator Rooms 3 and 4.

2. Summarize measures taken to mitigate potential choke points, and
3. Summarize the evaluation of water holdup at installed curbs and/or debris interceptors, and
4. Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.

TVA Response

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 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 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. Reflective metal insulation 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 choke-points.

Additionally, an inspection for non-LOCA generated material that could potentially obstruct recirculating water is conducted as part of the containment cleanliness inspection program prior to restart from an outage. The controlling procedure specifically addresses the need to assure that the containment is free of all items that could be washed to the sump.

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.

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.

TVA Response

The down stream effects of ingested debris during containment sump recirculation operation were evaluated for Sequoyah using the methodology documented in Revision 01 of Topical Report No. WCAP-16406-P (and the associated NRC SER). In accordance with this methodology, the effect of debris ingestion was evaluated for equipment in the ECCS and CSS systems including valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation. The equipment evaluations included erosive wear, abrasion, and potential blockage of flow paths. No exceptions were taken to the evaluation methodology for Sequoyah.

The significant assumptions applied to the Sequoyah evaluation is as follows:

General Assumptions

a. The screen mesh size for the original Sequoyah sump intake is 0.25 inches. The assumed debris size for hard objects in this evaluation shall also be 0.25 inches. Deformable objects of up to two times the sump screen hole size (0.50 inches) are assumed to pass through the sump screen, and are assumed to deform to pass through any downstream clearance equal to or larger than the sump screen hole size. The maximum Sequoyah advanced design strainer opening size is 0.095". The evaluation performed for a sump screen hole size of 0.25 inches will bound the strainer configuration.

b. The mission time for the Sequoyah ECCS and CSS equipment is assumed to be 30 days (or 720 hours).

c. The failure modes included in the pump evaluation are only those related to the pump itself (it does not include the motor, gear boxes, couplings, etc.). The debris loading in the fluid is assumed to only affect the internal components of the pump.

d. For the pump wear evaluation, a wear ring gap increase of up to three times the design clearance is assumed to have no significant impact on the hydraulic performance of the ECCS and CSS pumps.

Debris Size Assumptions

e. Fibrous debris and RMI particulate debris are assumed to be greater than 400 μm and hence will deplete per the adjusted wear model presented in the WCAP-16406-P.

f. All other particulate debris and the coatings debris within the ZOI of the break are assumed to be less than 100 μm due to the characteristic sizes and so will not deplete.

g. The unqualified coatings outside of the ZOI are assumed to fail in a size distribution with 94.0 percent of the unqualified coatings debris greater than 400 μm, 4.5 percent less than 400 μm, but greater than 100 μm, and 1.5 percent less than or equal to 100 μm. The size of the unqualified coatings ≤ 100 μm is assumed to be 50 μm on average.

Erosive and Abrasive Wear Models Assumptions

h. When applying the wear caused by the debris ingested through the sump screen, design conditions are assumed for the equipment with the exception of the pumps, where normal wear is taken into account,

i. The abrasive and erosive wear on pumps used for service during normal plant operation is assumed to not exceed 3.0 mils.

j. A debris depletion factor (λ) of 0.07 hr^{-1} is assumed for both abrasive and erosive wear for Sequoyah in Equation 7.2-1 from WCAP-16406-P, which accounts for the depletion of the sump debris.

k. For the evaluation of wear on pumps, debris particles smaller than 50 μm are assumed to cause only erosive wear on the pump internals. The design running clearances in the ECCS and CSS pumps typically range from 0.010 to 0.025 inches. The smallest clearance in these pumps is the radial gap, which is 0.005 inches (5 mils). Debris particles smaller than 50 μm are approximately 40 percent of this radial clearance and are therefore unlikely to cause abrasive wear.

l. Debris particles greater than 50 μm are conservatively assumed to cause abrasive wear of the pump internals.

2. Provide a summary and conclusions of downstream evaluations.

TVA Response

The results and conclusions of the Sequoyah down stream effects evaluation for containment sump recirculation ingested debris are as follows.

Valves

The ECCS and CSS valves were evaluated for erosive wear and plugging due to debris ingestion.

The detailed evaluation of the 24 Sequoyah Unit 1 and 2 ECCS injection flow balancing valves demonstrated that all valves in their evaluated positions will pass all debris for an assumed strainer opening diameter of 0.125 inches or less. All other ECCS and CSS valves have much larger openings and are not subject to plugging. All valves requiring detailed evaluation for sedimentation were found to have a sufficient flow velocity to preclude sedimentation ECCS valves that are closed prior to exposure to debris-laden fluid do not require an explicit flow calculation. The detailed erosion evaluation performed for each of the 24 ECCS throttle valves demonstrated acceptable 30-day erosion in all cases.

Pumps

Three aspects of pump performance were evaluated for debris ingestion effects. These included hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration).

For the hydraulic performance evaluation, only the RHR and CSS pumps required detailed evaluation. For these pumps, the increased clearances due to erosive and abrasive debris wear are less than three times the design clearance as shown below. Consequently, the hydraulic performance of the pumps is not affected by injected debris debris.

Pump Wear Hydraulic Evaluation Results

Pump	Total Wear (mils)	Design Clearance (mils)	Increased Clearance (mils)	3X Design Clearance (mils)
RHR	23.0	17	40.0	51
CSS	25.6	15	40.6	45

The mechanical shaft seal assembly performance evaluation confirmed the ability of the Sequoyah ECCS and CSS pumps to meet the acceptance criteria for backup seal bushing material and non-use of cyclone separators. This aspect of the pump design was concluded to be acceptable.

For the mechanical evaluation, the multi-stage SIP and CCP pumps were evaluated for an increase in the wear ring gap due to erosive, abrasive, and debris packing type wear. The post-accident wear ring stiffness was established for both the pump suction side (abrasive wear) and discharge side (packing wear) and then compared to the minimum stiffness required for successful pump operation as shown below. Since the post-accident wear ring stiffness exceeds the required minimum value, pump mechanical performance was concluded to be acceptable.

Pump Wear Mechanical Evaluation Results

Pump	Increased Clearance (mils)	Resultant Stiffness (lbf/mil)	Minimum Stiffness for Pump Operation (lbf/mil)
SIP - Suction	15.22	6.399	
SIP - Discharge	48.0	1.319	
Total Stiffness		**7.718**	7.327
CCP - Suction	16.22	3.819	
CCP - Discharge	51.65	0.453	
Total Stiffness		**4.274**	3.133

Heat Exchangers

Sequoyah ECCS and CSS heat exchangers were evaluated for tube plugging and tube failure due to erosive wear. The heat exchanger tube plugging evaluation confirmed that the inside diameter of all tubes are larger than the debris particle size. Consequently, tube plugging will not occur. For the heat exchanger wear evaluation, the actual tube wall thickness reduced by the thickness lost to erosion was found to be greater than the wall thickness required to retain system pressure. As such, tube failure due to erosion will not occur.

Orifices

Flow orifices in the ECCS and CSS system piping were evaluated for plugging and failure due to erosive wear. The orifice plugging evaluation confirmed that all ECCS and CSS orifice bore diameters are larger than the debris particle size. Consequently, orifice plugging will not occur. For the orifice wear evaluation, the increase in the orifice inner diameter caused by erosion resulted in an insignificant (less than 3 percent) increase in system flow. As such, the orifice performance was considered acceptable.

Spray Nozzles

Spray nozzles in the CSS system were evaluated for plugging and failure due to erosive wear. The spray nozzle plugging evaluation confirmed that all CSS spray nozzle diameters are larger than the debris particle size. Consequently, spray nozzle plugging will not occur. For the spray nozzle wear evaluation, the increase in nozzle diameter caused by erosion resulted in an insignificant (less than 10 percent) increase in system flow. As such, nozzle performance was considered acceptable.

Instrumentation

Instruments in the ECCS and CSS systems were evaluated for debris collection in the instrument sensing lines. The instruments of concern were those which are connected to the recirculating flow path through the ECCS or CSS systems and which must function post-accident to support application of emergency procedures. For the Sequoyah instrumentation sense line evaluation, the transverse ECCS recirculation flow velocity was found to be greater than minimum velocity for debris settlement (2.94 ft/sec). Consequently, failure of the instrumentation due to debris settlement in the sense lines will not occur.

An evaluation was also performed to address potential debris collection in the reactor vessel level instrumentation system (RVLIS). Debris collected in the reactor vessel lower plenum may affect the performance of the RVLIS in measuring reactor vessel water level during recirculation. For the Sequoyah RVLIS, the reactor vessel water level is measured with a differential pressure transmitter connected to the top and bottom of the reactor vessel. No active circulation will occur in the reactor vessel upper head volume, so no debris will affect the RVLIS upper connection. The low flows in the lower plenum combined with the fact that the RVLIS impulse lines are dead-ended will prevent both the entry of debris into the RVLIS connection and the collection of debris in sufficient quantity to affect the differential pressure transmitter. Debris settling in the lower plenum of the reactor vessel will not affect the Sequoyah RVLIS water level measurements.

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

TVA Response

No design or operational changes were made as a result of the debris ingestion downstream evaluations for Sequoyah.

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.

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 effects of ingested debris on the Sequoyah fuel and reactor vessel internals was initially performed using the methodology summarized in Topical Report No. WCAP-16406-P, Revision 01, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191." For the reactor vessel internals, the flow paths for cold leg and hot leg recirculation flow were reviewed and a dimensional analysis was performed to establish the minimum equipment clearances in the flow paths. The dimensional analysis established that all of the essential flow paths through the reactor internals are adequate to preclude plugging by sump debris. The limiting dimensions of the essential flow paths in the upper and lower internals were all greater than the analyzed maximum debris dimension. The maximum debris dimension was defined as two times the sump screen opening size. The Sequoyah containment sump maximum penetration opening is 0.0951 inches in diameter. The smallest clearance identified by the dimensional analysis was 0.50 inches. As such, the ingested debris was sufficiently small to preclude plugging in the vessel internals.

For the fuel assemblies, a simplified version of the method described in WCAP-16406-P was used for the Sequoyah evaluation. A screening evaluation was performed to determine if sufficient fiber could be collected on the fuel bottom nozzle to form a continuous fiber bed. If a continuous fiber bed thicker than 0.125" can form across the bottom of the fuel, further evaluation is required to confirm that that core flow remains adequate with the blockage. If a continuous fiber bed thicker than 0.125 inches cannot form across the bottom of the fuel, no further fuel evaluation is necessary.

For the Sequoyah screening review, evaluation of the cold-leg break established the high rate of bypass flow around the core precludes the formation of a fiber bed since most of the fibrous debris passing through the containment sump screen bypasses the core and is returned to the containment sump for further filtering. The fiber bed builds to a maximum of approximately 0.005 inches in 4 hours.

For the evaluation of the Sequoyah hot-leg break, the thickness of the fibrous bed formed on the bottom of the fuel did not reach a 0.125-inch thickness. The approximate overall fiber bed thickness for each sensitivity case for hot-leg breaks is as shown below.

Sequoyah Fuel Fiber Bed Thickness - Hot Leg Break

	95% fuel capture	**50% fuel capture**
95% sump screen capture	0.075 inches	0.040 inches
97% sump screen capture	0.045 inches	0.024 inches

Since a continuous fiber bed thicker than 0.125" was shown not to form across the bottom of the fuel for both cold-leg and hot-leg breaks, it was concluded that adequate cooling flow will be provided to the Sequoyah fuel assemblies.

These reactor internals and fuel blockage evaluations were then compared to 1) the evaluation of fuel clad temperature response to blockage at the inlet to the core, and 2) the evaluation of fuel clad temperature response to local blockages or chemical precipitation on fuel clad surfaces contained in Topical Report No. WCAP-16793-NP, Revision 00, "Evaluation of Long-Term Cooling

Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid." Based on the results of the initial Sequoyah reactor vessel internals and fuel blockage results performed in accordance with Topical Report No. WCAP-16406-P, it was concluded that the flow blockage evaluations in Topical Report No. WCAP-16793-NP will bound Sequoyah operating conditions without exception.

Additionally, the evaluation of chemical effects in the core region (including the potential for plate-out on fuel cladding) contained in Topical Report No. WCAP-16793-NP was reviewed for Sequoyah. Section 5.7 of Topical Report No. WCAP-16793-NP contains an evaluation of post-LOCA chemical reactions in the reactor core for long-term containment sump recirculation operation using the LOCA Deposition Analysis Model (LOCADM) developed by Westinghouse. A sample evaluation was performed using conservative plant chemistry values and operating conditions to evaluate the 1) effect of chemicals in the core region to form precipitation on the fuel cladding surfaces, and 2) the effect of the chemical deposits on fuel cooling. The sample evaluation demonstrated a maximum deposit thickness of 257 microns which resulted in a maximum fuel temperature during recirculation operations of 324°F. The evaluation concluded that long term cooling was not compromised based on these results.

A comparison to the conditions evaluated by the sample calculation in Topical Report No. WCAP-16793-NP was made to Sequoyah plant chemistry values and operating conditions. The results of the comparison are summarized as follows.

Comparison of LOCADM Sample Calculation Parameters to Sequoyah Plant Conditions

Parameter	Sample Calculation	Sequoyah
Core Thermal Power Rating	3188 MWt	3455 MWt
Fiber (Fiberglass) Debris Load	7000 ft^3	12.5 ft^3
Calcium Silicate Debris Load	80 ft^3	None
Sump pH Control Buffer Agent	Sodium Hydroxide	Sodium Tetraborate
Hot Leg Switchover Time	13 hours	5 hours
Aluminum Surface Area in Containment	15,988 ft^2	1,427 ft^2

Based on this comparison, it was concluded that the sample calculation in Topical Report No. WCAP-16793-NP was conservative with respect to Sequoyah service conditions. As such, chemical effects in the Sequoyah core region do not compromise long term core cooling. A Sequoyah plant specific LOCADM calculation will be performed to confirm this conclusion.

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.

- 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

Sequoyah uses sodium tetraborate as a buffering agent for the boric acid in the primary system and from the RWST. The post-accident pH of the Sequoyah containment sump recirculation inventory ranges from 8.0 to 8.4. This is considerably below the values used in the integrated chemical effects testing for either sodium hydroxide or sodium tetraborate. Additionally, the Sequoyah debris inventory contains only assumed amounts latent fiber in extremely small quantities. Due to the lack of fiber in the accident debris inventory, the deposition of chemical precipitants on fiberglass fibers as experienced in the integrated chemical effects tests will not have any effect on the head loss across the Sequoyah sump strainers. The Sequoyah strainer assembly is fabricated from stainless steel. Stainless steel is also the predominant debris material in the post LOCA sump recirculation pool. If any precipitant were to plate out on stainless steel, the majority of the plate out would occur on stainless surfaces other than the strainer.

Based on these considerations, it was concluded that detailed evaluations of chemical sump blockage effects are not warranted for Sequoyah as would be the case if a fiber bed could form on the sump strainer surface. A 10 percent increase in the strainer debris head loss was applied to the Sequoyah ECCS and CSS NPSH evaluations to conservatively account for any increased strainer blockage due to chemical effects. If further industry testing or experience establish that this value is insufficient, significant excess NPSH margin is available (refer to the response to Item 3.g.16) to allow for an increase in this margin allotment.

The effect of chemical deposits downstream of the sump intake screens have been addressed as discussed in the response to Item 3.n.1 above.

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 original containment sump intake structures were replaced with advanced designed strainers during the Unit 1, Cycle 15 refueling outage in the fall of 2007 and the Unit 2, Cycle 14 refueling outage in the fall of 2006. The Sequoyah design and licensing bases have been updated in accordance with the Sequoyah design change control process to reflect the addition of the sump strainers and to adopt the supporting analyses as the plant analyses of record.

Prior to the issuance of GL 2004-02, the Sequoyah licensing basis included a two-dimensional physical transport model to evaluate containment sump blockage effects for containment sump recirculation operation. This transport model was not consistent with the requirements of GL 2004-02 and was replaced with the three-dimensional transport model described in the response to Item 3.e above. Application of the three-dimensional transport model was considered to be an analysis methodology change and was submitted for NRC review and approval as Sequoyah

Technical Specification Change No. TVA-SQN-TS-06-02 by a TVA letter dated May 25, 2006. NRC review and approval of the revised transport methodology was documented in the NRC Safety Evaluation Report (SER) submitted to TVA by a letter dated November 07, 2006.

No other changes to the Sequoyah licensing and design basis are required to support the analysis and modifications performed in response to GL 2004-02.

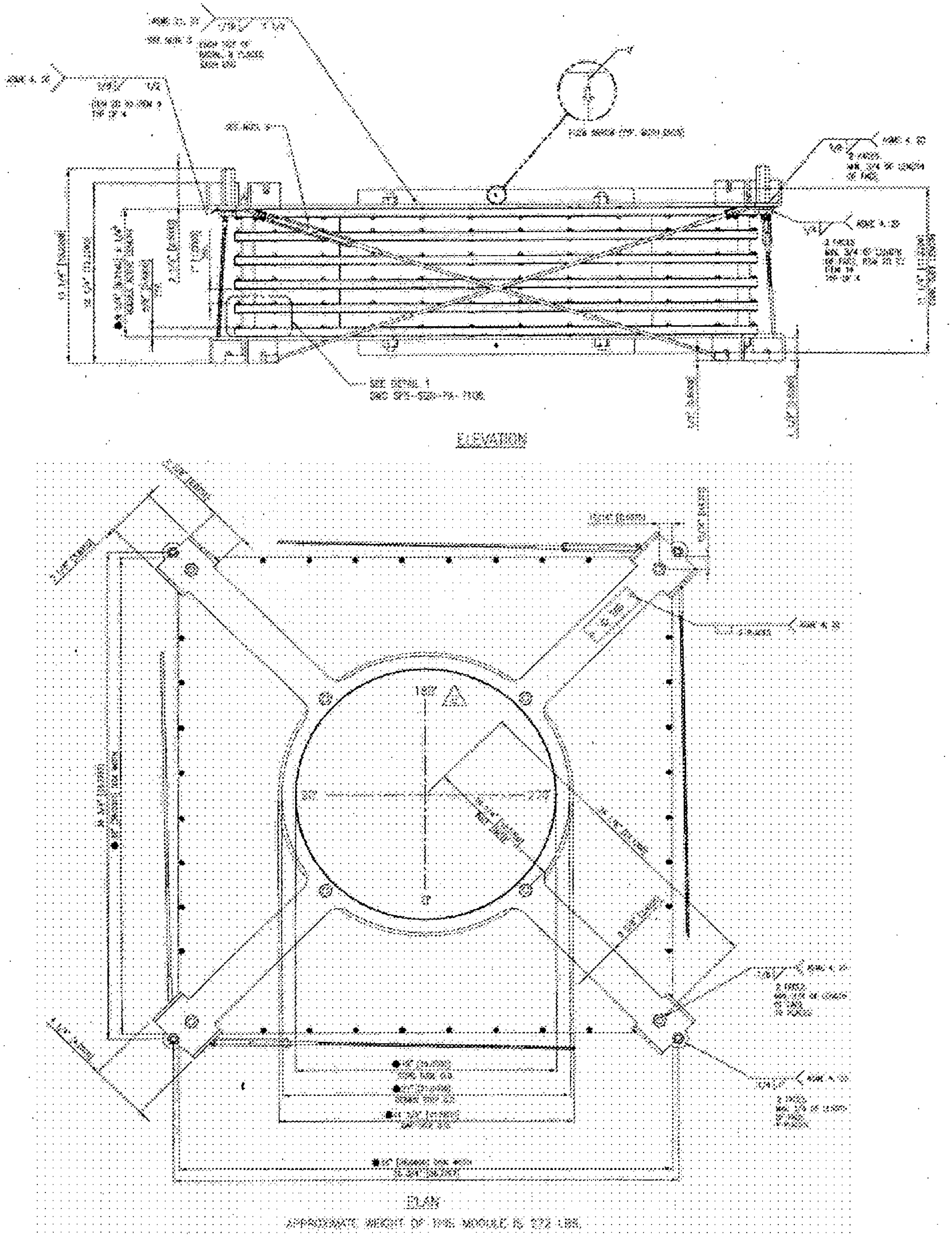

Figure 3.j.1-1 – PCI Sure-Flow Strainer 6 Disk Module Assembly

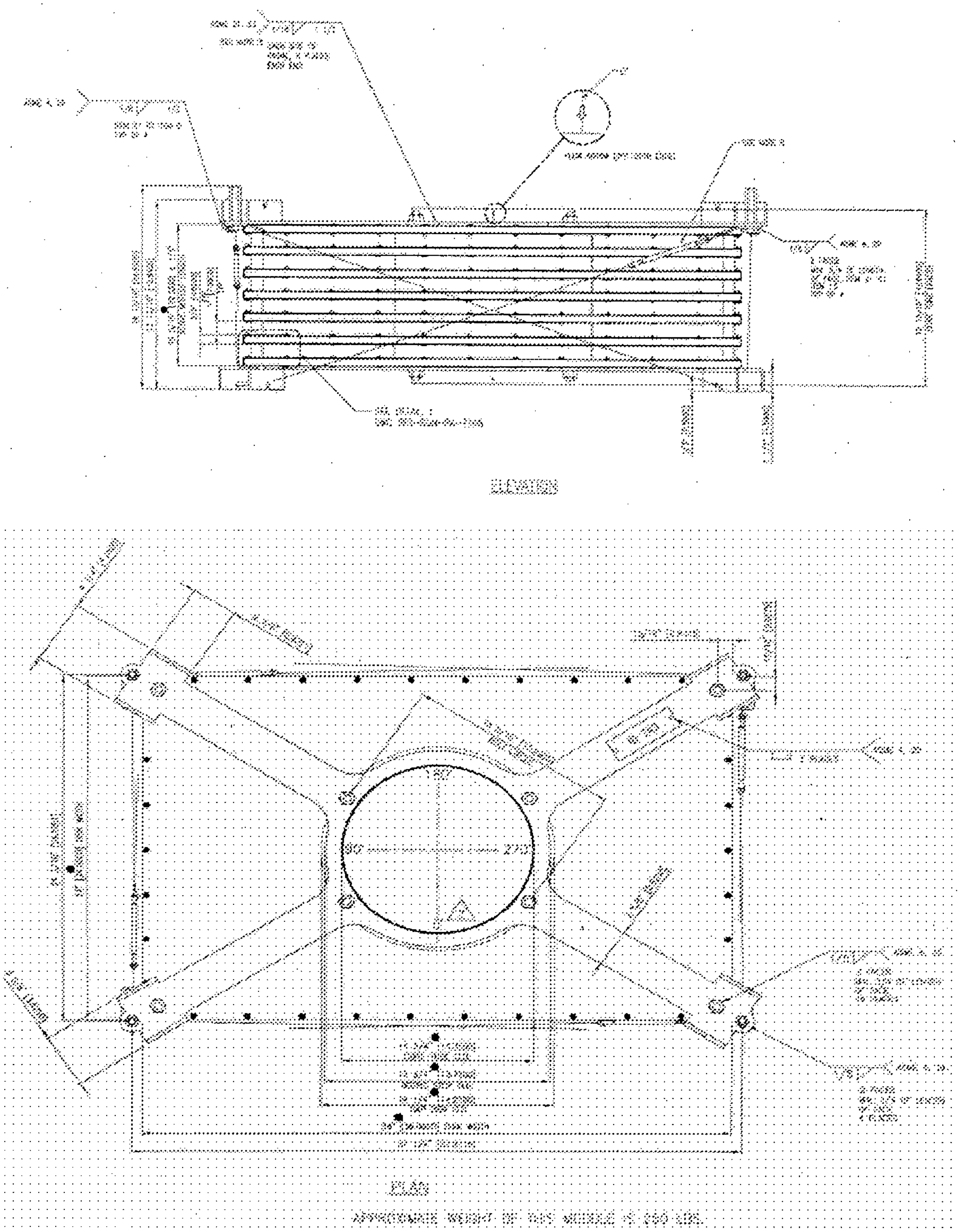

Figure 3.j.1-2 – PCI Sure-Flow Strainer 7 Disk Module Assembly

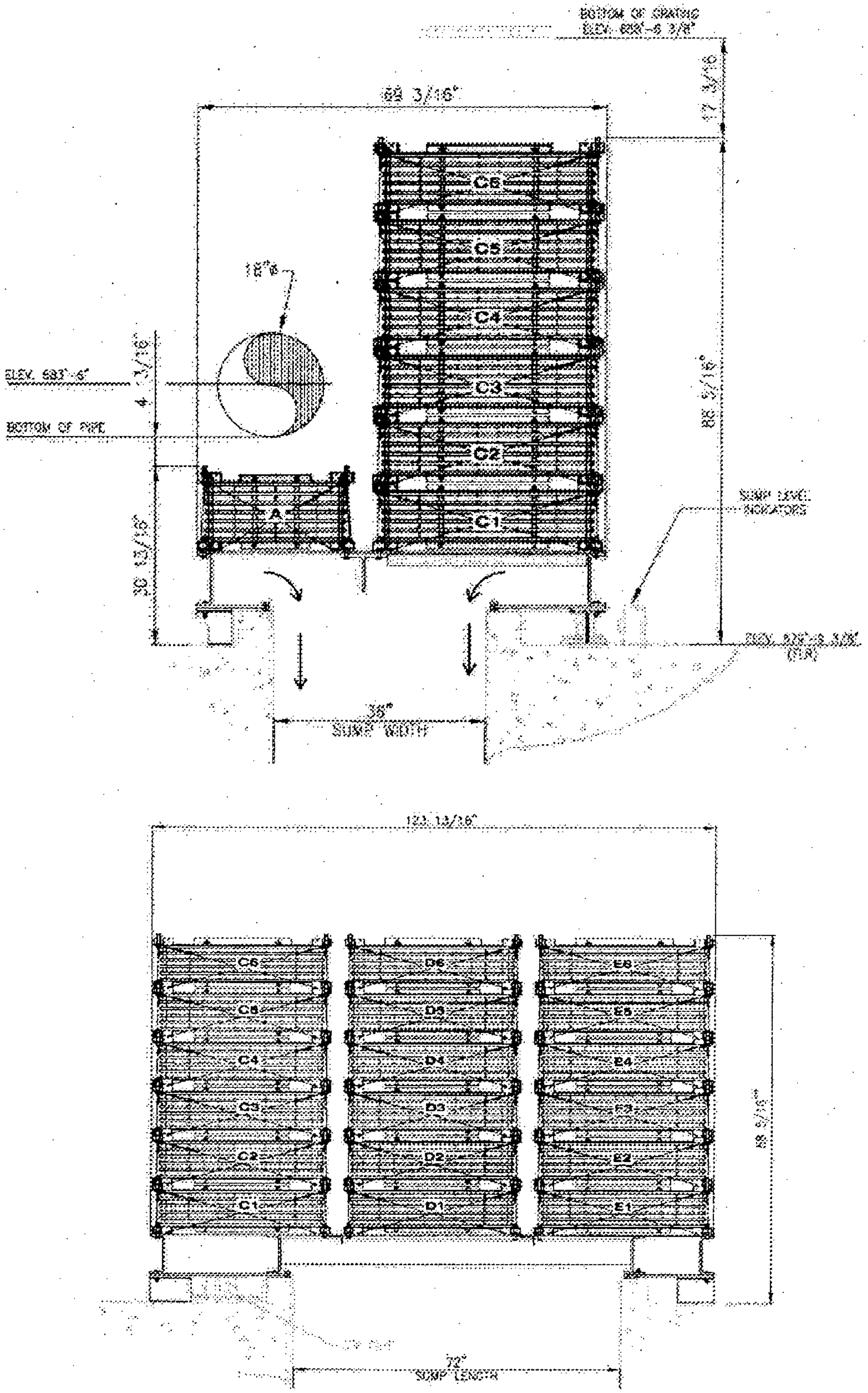

Figure 3.j.1-3 Sequoyah Containment Sump Strainer Assembly