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

September 1, 2006

TVA-SQN-TS-06-02 10 CFR 50.90

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	)	50-328

SEQUOYAH NUCLEAR PLANT (SQN) UNITS 1 AND 2 - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI) FOR TECHNICAL SPECIFICATION CHANGE 06-02 (TAC NOS. MD2052 AND MD2053)

Reference: NRC letter to TVA dated August 11, 2006, Sequoyah Nuclear Plant, Units 1 and 2 - Request for Additional Information Regarding Containment Sump Design Changes (TAC Nos. MD2052 and MD2053)

The purpose of this letter is to provide TVA's response to NRC's RAI letter (reference letter). TVA's response to the RAI supports NRC's review of SQN Technical Specification Change 06-02.

The enclosure provides the TVA responses. There are no commitments contained in this submittal.

Please direct questions concerning this issue to J. D. Smith at (423) 843-6672.

D030

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 1st day of September, 2006.

Sincerely,

P. L. Pace
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Industry Affairs

Enclosure:
TVA Response to Request for Additional Information

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ENCLOSURE

SEQUOYAH NUCLEAR PLANT (SQN)
UNITS 1 AND 2
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI)

The following provides TVA's response to NRC's RAI letter dated August 11, 2006.

NRC Request

(a) Please specify the difference in the results of the current two-dimensional model and the proposed computational fluid dynamics (CFD) transport analysis.

TVA Response

The main differences between the two-dimensional transport model and the three-dimensional CFD transport model are as follows.

Coatings Debris Transport

The two-dimensional transport model established the amount of coating debris transported to the sump intake using a sump radius of influence analysis. The model combined a two-dimensional flow field in the containment recirculation pool with appropriately-sized coating debris settling velocity data to establish a debris transport radius of influence around the sump intake. Using the settling velocity data, the debris trajectories within the recirculation pool flow were predicted. The sump intake radius of influence was defined to be the maximum distance from the sump at which debris of a certain size could be transported to the sump intake before settling to the floor. Any debris that settled to the floor was not considered in the sump screen blockage evaluation. Any debris within the radius of influence was assumed to transport to the sump intake and was included in the blockage analysis. Using this information, combined with the initial debris distribution, the following debris transport fractions were established:

- Unqualified Alkyd coating: $F_{transport}$ = 13%
- Qualified Epoxy coating (applied to concrete surfaces): $F_{transport}$ = 8%
- Qualified Epoxy coating (applied to steel surfaces): $F_{transport}$ = 16%

The amount of coating debris that was determined to transport using the three-dimensional CFD model was calculated using a turbulent kinetic energy (TKE) analysis. The minimum TKE required to suspend debris of a certain size is defined by the following equation:

$$TKE = \frac{1}{2}\overline{3 \cdot u_3^2} = \frac{3}{2}V_{settling}^2$$

Where u_3 is defined as the vertical component of the velocity fluctuation,

and $V_{settling}$ is defined as the settling velocity of the debris.

(The overbar denotes time averaging)

Using the particle settling velocity data, the minimum TKE required to suspend the particulate debris was computed. The debris transport calculation computed the TKE distribution in the containment recirculation pool. Debris residing in regions in which the computed TKE exceeded the minimum TKE required for suspension was deemed transportable to the sump. In addition, all failed coatings were assumed to fail as fine debris. Using this methodology, the debris transport fractions for the coating debris types listed above was 100 percent (%).

Ice Condenser Washdown Transport

The two-dimensional model determined that 3 of the 20 ice condenser bays could wash failed coatings into the sump intake radius of influence. It was determined that 176 square feet (ft^2) of the unqualified coatings in containment could be blown down to the ice condensers. Only 3 ft^2 of the failed coatings in the ice condenser (2%) were determined to washdown to lower containment.

In contrast, the CFD model assumed that 100% of the fine debris was blown into the ice condenser. Since all failed coatings were assumed to fail as fine debris, 100% of the failed coatings were assumed to blowdown to the ice condensers. It was conservatively assumed that all fine debris in the ice condensers was washed down into lower containment.

Spray Flow Washdown Transport

The two-dimensional model used a flow field model and a debris trajectory model to determine the amount of the failed coating debris that would transport to lower containment via the refueling canal drains. These models determined that 100% of the quantity of debris that washed down to lower containment would settle to the floor and would not reach the sump.

The CFD model assumed that 100% of the failed coating debris in upper containment would be washed down by the containment sprays through the refueling canal drains. The transport fractions of the failed coating debris that reached lower containment were then computed using the TKE model described above.

Nukon™ Insulation Transport

The two-dimensional model stated that the pressurizer safety valve loop seals were temporarily wrapped with Nukon™ fiberglass insulation. A flow field model was developed to determine the amount of transportable Nukon™ in the event of a small pipe break failure in the vicinity of the loop seals. The results of the analysis showed that there is insufficient flow velocity to transport submerged fragmented fibrous debris. Approximately 9 ft^2 of the intact Nukon™ that is dislodged from the piping was determined to transport to the sump.

At the time that the CFD transport analysis was executed, all Nukon™ fiberglass insulation had been removed from the SQN containment.

Reflective Metal Insulation (RMI) Transport

The two-dimensional model used the methodology given in NUREG/CR-2791 to determine the RMI debris transport fraction. The model determined that a maximum of 45% of the sump screen area could be blocked by RMI debris.

The CFD model established the flow field velocity and TKE distribution in the containment recirculation pool. Combining the flow field analysis with the minimum tumbling velocity and TKE metrics required to transport RMI debris, the maximum debris transport fraction was determined to be 51%. The debris transport fraction was applied to the total quantity of RMI debris generated to establish the effect on sump intake blockage.

<u>**NRC Request**</u>

(b) Watts Bar and Sequoyah are similar plants. The staff is currently performing an audit of the Watts Bar sump modifications and has gained a broad understanding of the proposed changes. To what extent do the two units have the same transport analysis? Please provide the inputs,

boundary conditions, geometry, that were different from Watts Bar's transport analysis (if any).

TVA Response

Both the Sequoyah (SQN) and Watts Bar (WBN) debris transport analyses were performed at the same time. The same computer-aided design (CAD) software (MechanicalDesktop® 2005) and CFD modeling software (Flow-3D® Version 9.0) were used for each analysis. The methodology used to model blowdown, washdown, pool fill, and recirculation transport was the same for each analysis. The CFD model used in each analysis employed similar computational mesh configurations and boundary conditions. The break, containment spray, and ice melt drainage flows were modeled in a similar fashion for each analysis. The containment sump and the turbulence in the containment recirculation pool were modeled similarly for each analysis.

The differences between the transport models are primarily due to plant specific configuration differences. The main differences between the WBN and SQN debris transport analyses are provided below.

Table 1 - Comparison of Sequoyah and Watts Bar Design Input

Parameter	Sequoyah Input Value	Watts Bar Input Value
Maximum 2 pump RHR pump flow gallons per minute (gpm)	4,200 x 2	4,550 x 2
Maximum 2 pump CS pump flow (gpm)	5,220 x 2	5,000 x 2
Maximum sump flow (gpm)	18,840	19,100
Minimum time to initiate recirculation seconds (sec)	485	600
Maximum ice melt drainage flow (gpm)	4,194	5,210
Water level for recirculation transport (ft)	9.06	8.21
Maximum spray flow rate (gpm)	10,440	10,000
Ice melt discharge elevation (ft)	716.5	739.5
Reactor input nozzle elevation (ft)	695	718
Freefall distance from break to pool surface (ft)	6.16	7.01
Baffle porosity	0.2349	0.2386

Geometry:

The sump cavity volume for SQN and WBN was 461 cubic feet (ft^3) and 680 ft^3, respectively. The total water volume for the sump recirculation pool depth of 6 inches for SQN and WBN was 1,693 ft^3 and 1,747 ft^3, respectively. The geometrical differences outlined above caused the pool fill transport fractions for SQN and WBN to be 27% and 39%, respectively.

Figures 1 and 2 show the containment plan views for SQN and WBN. Aside from the difference in elevation at which each view is taken, there are slight differences in the overall layout of each containment. These differences are displayed in the figures below:

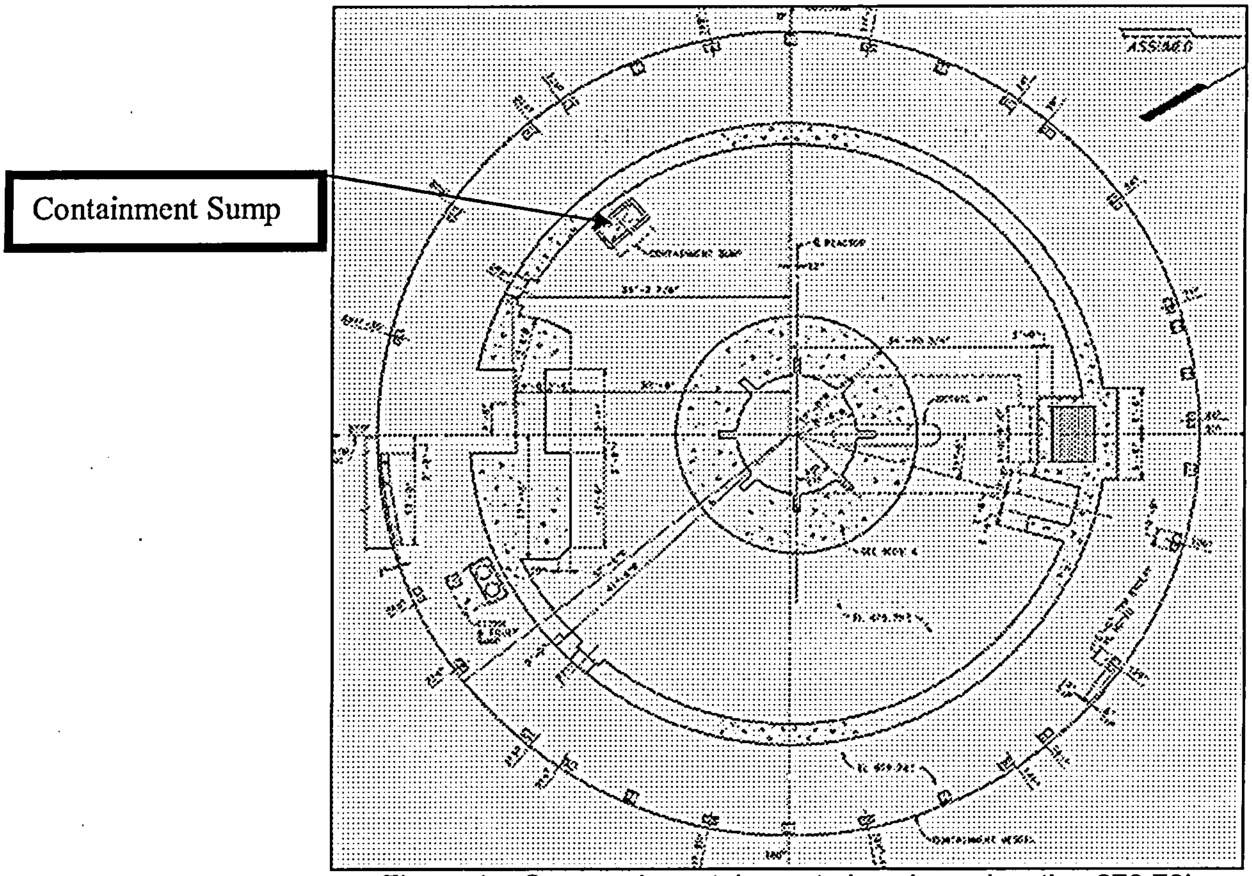

Figure 1 – Sequoyah containment plan view, elevation 679.78'

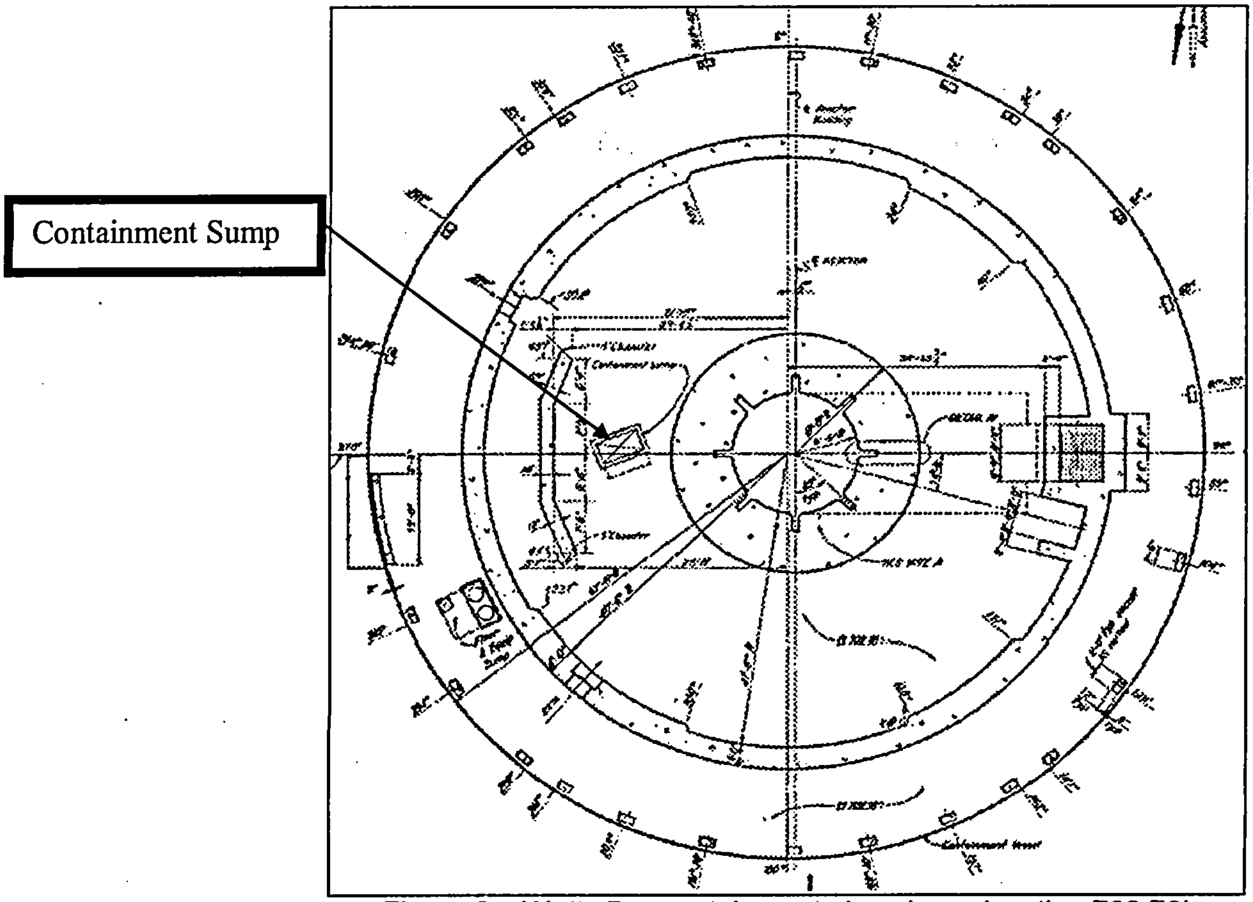

Figure 2 – Watts Bar containment plan view, elevation 702.78'

The existing sump geometry for SQN and WBN are also different. The SQN sump is housed in a small box that occupies an area of 28.0 ft^2. The WBN sump is housed in a sump room that occupies an area of 395.4 ft^2. Figures 3 and 4 display the containment sump geometry for each plant.

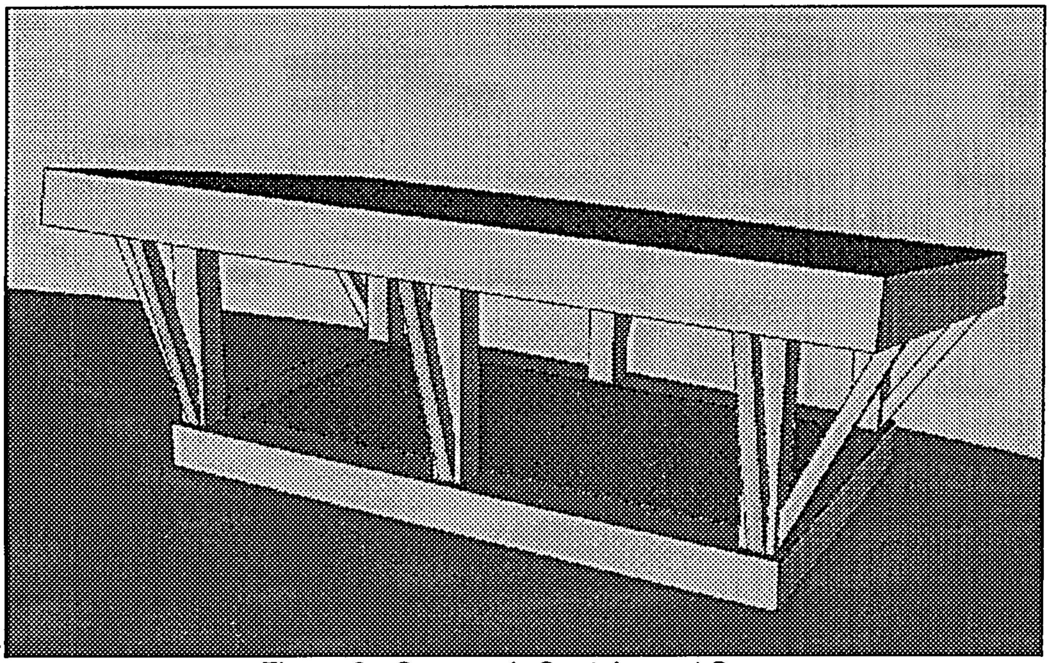

Figure 3 - Sequoyah Containment Sump

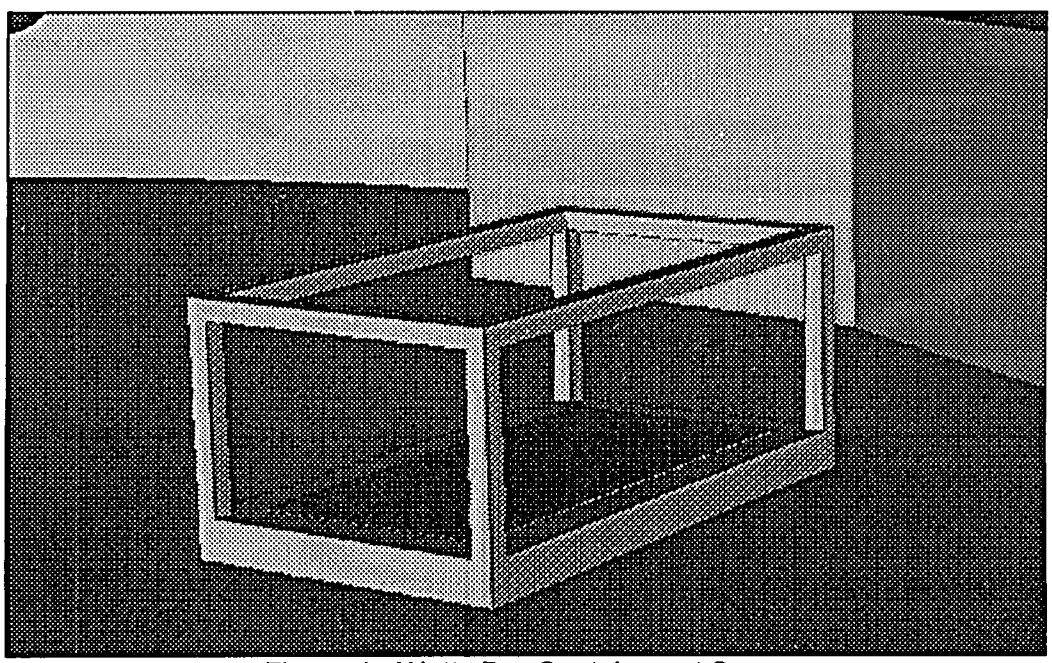

Figure 4 - Watts Bar Containment Sump

NRC Request

(c) SQN stated in the license amendment request (LAR) that "the quantity of debris washed down by ice melt and spray was conservatively determined." Please provide more details of how the amount of debris was determined.

TVA Response

The fraction of failed coating debris blown upward into the ice condenser was conservatively assumed to be 100%. This assumption is considered reasonable since ice condenser plants relieve steam from a blowdown into the ice condenser, and fine debris generated by a pipe break loss-of-coolant accident (LOCA) jet would be easily entrained and carried with the blowdown flow.

It was conservatively assumed that all of the debris blown into the ice condenser would also be trapped and subsequently washed back down through the ice condenser drains. It was also assumed that failed coatings in upper containment would be washed down by the containment sprays through the refueling canal drain lines. The following debris types were determined to have 100% washdown transport fractions to lower containment. The washdown transport fractions are applicable to all analyzed break cases.

- Phenolic paint inside the ZOI
- Inorganic Zinc paint inside the ZOI
- Modified silicon paint inside the ZOI

The RMI debris was assumed to remain in lower containment where it would not be washed down by ice melt and spray flow.

NRC Request

(d) Please provide the basis for SQN to conclude that the appropriate ice melt and containment spray flow rates, and kinetic energy were used in the CFD calculation.

TVA Response

Containment Spray Flow

SQN's upper containment is designed to drain containment spray into the refueling canal where it drains through two 14-inch pipes into the lower containment recirculation pool. A small quantity of spray water also passes through the air return fans, where it drains through two of the accumulator rooms to the containment recirculation pool. (This flow was determined to have an inconsequential affect on the pool.) The maximum design basis total spray flow rate is 10,440 gallons per minute (gpm) which was assumed to be equally split between the two refueling canal drains.

Ice Melt Flow

Based on a minimum time to the initiation of recirculation of 485 seconds (8.08 minutes), the maximum ice melt drainage flow after recirculation is 4,194 gpm. Ice melt flows through 20 drain lines discharging at an elevation of 716.5 ft at various points around the perimeter of the reactor building polar crane wall. This draining water impacts a number of obstacles (grating, equipment, steel beams, etc.), which break up the individual streams into large droplets. It was assumed that the ice melt drainage would flow uniformly through the 20 drains.

Introduction of ice melt drainage flows to the containment pool model was accomplished as follows:

- At SQN, the farthest distance that ice melt water could fall before hitting the floor is 36.7 ft (the difference between the 679.78 ft floor elevation and the drain discharge at the 716.5 ft elevation). This gives a freefall velocity of 48.6 feet per second (ft/s). However, the terminal velocity of a large raindrop is only 29 ft/s. Therefore, a velocity of 29 ft/s was used to calculate the kinetic energy imparted to the pool. This is conservative since smaller drops have a lower terminal velocity.

- The ice melt flow was initially introduced at points below the drain lines (two points were moved slightly due to the location of sump and the incore tunnel entrance).

Kinetic Energy

Kinetic energy was initially modeled in the CFD calculation in the following ways:

- The kinetic energy of the falling droplets and streams was accounted for through a consideration of the first law of thermodynamics (the conservation of energy).
- The kinetic energy from the ice melt drainage was initially introduced to the CFD model at the containment floor. This was considered conservative as it imparts the stirring influences of the drainage right where debris might be trying to settle.
- Since the addition of the ice melt flow creates a transient condition (raising the water level), the kinetic energy was introduced without introducing the flow to allow the CFD simulation to reach steady state.

Subsequent to the initial analysis, the SQN debris transport analysis was reperformed to address the Fort Calhoun audit finding concerning the spray modeling errors (similar to the WBN debris transport reanalysis). The details regarding the changes to the CFD spray model made for the reanalysis are as follows:

Because of Flow-3D® code limitations associated with modeling disperse inflows, the original SQN modeling introduced ice melt drainage at the bottom of the pool rather than at the surface. Tangential velocity components were used in an effort to introduce the drainage at a velocity consistent with the terminal velocity of a large rain drop. However, the tangential velocities were ill-defined such that the drainage was introduced at too low of a velocity. The code limitations necessitating the introduction of containment ice melt drainage at the bottom of the pool were addressed by a revision of the analysis code which includes logic allowing much more disperse modeling of inflows (i.e., Flow-3D®, Version 9.0. which was verified and validated in accordance with Document No. ALION-PLN-ALION-2507-03, R/0, "Flow-3D® Version 9.0 Verification and Validation"). The revised code allows flow to be introduced at varying flow rates and velocities at up to 10,000 discrete locations anywhere in the computational domain. The revised code was used in the SQN reanalysis to introduce containment ice melt drainage at the surface of the pool. The drainage was introduced in the same patterns at the same flow rates as in the original analysis at a velocity of 29 ft/s.

In addition to modeling ice melt drainage at the pool surface, the updated analysis code allowed the flow from the analyzed pipe break to be introduced more realistically. This change resulted in less stirring (turbulence) in the vicinity of the pipe break for the SQN reanalysis.

The SQN reanalysis did not demonstrate any underestimation in the debris transport fractions as calculated by the original analysis.

NRC Request

(e) Please provide the basis for SQN to conclude that the appropriate turbulence model was selected for the CFD calculations.

TVA Response

Several different turbulence modeling approaches can be selected for a Flow-3D® calculation. The approaches are (ranging from least to most sophisticated):

- Prandtl mixing length
- Turbulent energy model
- Two-equation k-ε model
- Renormalized group theory (RNG) model
- Large eddy simulation model

The RNG turbulence model was determined to be the most appropriate for this CFD analysis due to the spectrum of modeled dimensions that exist in the containment pool during emergency recirculation. The RNG approach applies statistical methods in a derivation of the averaged equations for turbulence quantities (such as turbulent kinetic energy and its dissipation rate). RNG-based turbulence schemes rely less on empirical constants while setting a framework for the derivation of a range of models at different scales. Sensitivity calculations have shown that Flow-3D® containment pool calculations utilizing the more sophisticated turbulence models (the RNG model included) give results that differ significantly from calculations utilizing the less sophisticated models. Differences in results between calculations made with the more sophisticated models have shown to be slight.

NRC Request

(f) Statement number 11 in the Debris Transport Methodology section of the LAR, states that "the quantity of debris that could experience erosion due to the break flow, spray flow, or ice melt drainage was determined." Please provide more details of the fraction of erosion and types of debris.

TVA Response

The erosion evaluation item was included in the LAR to completely describe all aspects of the basic transport methodology. Based on SQN plant walkdowns, the only type of insulation debris that would be destroyed in any of the postulated breaks is stainless steel RMI. Since RMI does not break down into smaller pieces following the initial generation, erosion is not a factor in the SQN plant specific debris transport analysis.