TVA

Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402-2801

November 30, 2011

10 CFR 50.4
10 CFR 50.46

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

Sequoyah Nuclear Plant, Units 1 and 2
Facility Operating License Nos. DPR-77 and DPR-79
NRC Docket Nos. 50-327 and 50-328

Subject: **10 CFR 50.46 Annual Report of Non-Significant Changes**

References:
1. TVA Letter to NRC, "10 CFR 50.46 Annual Report," dated November 30, 2010
2. TVA Letter to NRC, "Responses to Requests for Additional Information Regarding 10 CFR 50.46 Annual Report," dated July 28, 2011

The purpose of this letter is to provide the current status of the calculated peak cladding temperature (PCT) for the Sequoyah Nuclear Plant, Units 1 and 2, emergency core cooling system (ECCS) evaluation model. This submittal satisfies the annual reporting requirements in accordance with 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," paragraph (a)(3)(ii). The enclosed report provides a summary of the changes to the calculated PCT for the limiting ECCS analysis, including the changes made since submittal of the reference letters.

A002

There are no regulatory commitments in this letter. Please direct questions concerning this issue to Clyde Mackaman at (423) 751-2834.

Respectfully,

J.W. Shea

Enclosure: 10 CFR 50.46 Annual Report of Non-Significant Changes

cc (Enclosure):

NRC Regional Administrator – Region II
NRC Senior Resident Inspector – Sequoyah Nuclear Plant

CDM:JWS
bcc (Enclosure):

Mr. Joshua L. Parker
AREVA NP, Inc.
P.O. Box 10935
Lynchburg, Virginia 24506-0935

NRC Project Manager - Sequoyah Nuclear Plant

G. P. Arent
T. J. Bradshaw (NSRB Support)
C. Carey
J. T. Carlin
G. M. Cook
D. E. Jernigan
C. D. Mackaman
G. W. Mauldin
J. S. McCary
P. T. Noe
P. D. Swafford
E. J. Vigluicci
R. J. Whalen
EDMS

P:\Licensing and Industry Affairs\CorpLicensing\NuclearLicensing\corp_lic\NRC\Sequoyah\10 CFR 50.46 Annual Report\2011 Report\SQN 50.46 Annual Report - 2011 CDM.docx.

ENCLOSURE

TENNESSEE VALLEY AUTHORITY (TVA)
SEQUOYAH NUCLEAR PLANT (SQN)
UNITS 1 AND 2

10 CFR 50.46 ANNUAL REPORT OF NON-SIGNIFICANT CHANGES

In accordance with the annual reporting requirements of 10 CFR 50.46(a)(3)(ii), the following is a summary of the limiting design basis loss-of-coolant accident (LOCA) analysis results established using the current SQN emergency core cooling system (ECCS) evaluation model.

The topical reports used for the large break LOCA (LBLOCA) and small break LOCA (SBLOCA) evaluations are listed in the administrative section of the SQN Technical Specifications as approved Core Operating Limits Report methods:

1. The LBLOCA evaluation methodology is based on EMF-2103P-A, Revision 0, with Transition Package as documented in ANP-2655P, Revision 1, which uses the S-RELAP5 code; and,

2. The SBLOCA evaluation methodology is based on BAW-10168P-A, Revision 3, which uses RELAP5/MOD2-B&W, Version 27.

The analysis of record (AOR) for SQN, Unit 1, for the LBLOCA was issued in 2008 and determined the peak cladding temperature (PCT) to be 1809 degrees Fahrenheit (°F). The SQN, Unit 1, plant specific analysis is detailed in Topical Report No. ANP-2695P, Revision 0, "Sequoyah Unit 1 Realistic Large Break Loss-of-Coolant Accident Analysis." This report was submitted to the Nuclear Regulatory Commission (NRC) as part of SQN, Unit 1, Technical Specification Change TS-08-01. The plant-specific application analysis was found to be acceptable as discussed in the NRC Safety Evaluation Report, dated September 24, 2008.

The AOR for SQN, Unit 2, for the LBLOCA was issued in 2007 and determined the PCT to be 2002 °F. The SQN, Unit 2, plant specific analysis is detailed in Topical Report No. ANP-2655P, Revision 1, "Sequoyah Unit 2 Realistic Large Break Loss-of-Coolant Accident Analysis." This report was submitted to the NRC as part of SQN Technical Specification Change TS-07-04. The plant-specific application analysis was found to be acceptable as discussed in the NRC Safety Evaluation Report, dated April 10, 2008.

The AOR for SQN, Units 1 and 2, for the SBLOCA was issued in 2008 and determined the PCT to be 1403 °F. The SQN, Units 1 and 2, plant specific analysis is detailed in AREVA NP Calculation 51-5006843-001, "SQN SBLOCA Accident Analysis Profile." This SBLOCA analysis was not required to be reviewed and approved by the NRC.

The following Table lists the changes to the PCT that have occurred since the AOR for SQN, Units 1 and 2. These changes can be summarized as:

- The LBLOCA PCT for SQN, Unit 1, increased 11 °F relative to the AOR due to the changes, and results in a current net licensing basis PCT of 1820 °F

- The LBLOCA PCT for SQN, Unit 2, increased 19 °F relative to the AOR due to the changes, and results in a current net licensing basis PCT of 2021 °F

- The SBLOCA PCT for SQN, Units 1 and 2, remains unchanged from the AOR, with a net licensing basis PCT of 1403 °F.

Report Year	Description	LBLOCA PCT (°F)	Change in LBLOCA PCT (°F)*	SBLOCA PCT (°F)*	Change in SBLOCA PCT (°F)*	Note
2008	AOR PCT	1809 (Unit 1) 2002 (Unit 2)		1403		
2008	Cold leg condensation under-predicted following cold leg accumulator injection		0		0	1
2009	Thermal radiation heat transfer under-predicted		+5		0	2
2009	Reactor kinetics model coding error and heat conduction algorithm logic error		-30		0	3
2009	Fuel pellet thermal conductivity degradation		0 (Unit 1) +8 (Unit 2)		0	4
2010	Liquid entrainment under-predicted in the steam generator tubes		+12		0	5
2011	High head ECCS injection delay time increase		+24		0	6
2011	Upper plenum modeling inhibits vapor flow into the top of the hot bundle		0		0	7
2011	Updated (net) licensing basis PCT	1820 (Unit 1) 2021 (Unit 2)		1403		

*For both SQN, Units 1 and 2, unless otherwise noted.

Notes:

1) Cold leg condensation under-predicted following cold leg accumulator injection

The LBLOCA analysis methodology under-predicts condensation in the reactor coolant system (RCS) cold leg after the accumulators empty. Because of this, the ECCS water entering the downcomer is sufficiently subcooled that it absorbs the downcomer wall heat without significant boiling. The lack of boiling in the downcomer leads to a higher water level in the core during reflood and a lower PCT. The condensation in the cold legs was increased by using very large multipliers on the interphase heat transfer in the cold legs. This resulted in saturated water entering the downcomer after cold leg accumulator injection. Sensitivity studies were performed using this revised model and no change in LBLOCA PCT was predicted. Boiling in the downcomer is only significant in LBLOCAs, so the SBLOCA PCT was not affected.

2) Thermal radiation heat transfer under-predicted

The LBLOCA analysis methodology accounts for thermal radiation heat transfer between the fuel and the reactor coolant. The model contains a correlation for determining water vapor emissivity and this correlation contained errors that resulted in the wrong values for water vapor emissivity being determined by the correlation. The water vapor emissivity correlation was corrected, and based on sensitivity studies, a bounding increase in LBLOCA PCT was determined to be 5 °F. The thermal radiation heat transfer model used in the LBLOCA methodology is not used in the SBLOCA methodology.

3) Reactor kinetics model coding error and heat conduction algorithm logic error

The LBLOCA analysis methodology accounts for the change in core power during the LBLOCA using a reactor point kinetics model. The point kinetics model in the version of RELAP5 used for the LBLOCA analysis was found to contain errors in the numerical solution algorithm indices and convergence criteria, which could affect the determination of transient core power. The version of RELAP5 used for the SBLOCA analyses did not contain these algorithm errors.

The LBLOCA analysis methodology accounts for conduction heat transfer in the fuel rods in its determination of PCT. The transient conduction heat transfer solution algorithm used in the methodology contained a logic error that assigned the heat capacity of the right boundary mesh point (N) from the next to last mesh point (N-2) instead of the adjacent mesh point (N-1). The SBLOCA methodology did not use the same transient conduction heat transfer algorithm as the LBLOCA methodology.

The point kinetics and heat conduction code errors were corrected in the version of RELAP5 used for the LBLOCA analysis, and sensitivity studies were performed using the updated computer program. These sensitivity studies established a 30 °F reduction in LBLOCA PCT.

4) Fuel pellet thermal conductivity degradation

In the LBLOCA methodology, the initial fuel pellet temperature distribution was being determined using a model that under-predicts the degradation in fuel pellet thermal conductivity at high core burn-ups. This resulted in lower initial fuel pellet temperatures being predicted and reduced initial fuel pellet stored energy. A proportional adjustment to the fuel temperature calculation was determined by comparing the fuel pellet temperature predications from the model to fuel pellet temperature data. The higher initial fuel pellet temperatures were assessed for their affect on PCT based on the time that PCT occurs. For SQN, Unit 1, PCT occurs during blowdown (<100 seconds), which resulted in no change in PCT from the higher initial fuel pellet temperatures. For SQN, Unit 2, PCT occurs during reflood (>100 seconds), which resulted in an 8 °F increase in LBLOCA PCT from the higher initial fuel pellet temperatures.

In the SBLOCA methodology, the initial fuel pellet temperature distribution was also being determined using a model that under-predicts the degradation in fuel pellet thermal conductivity at high core burn-ups. This resulted in lower initial fuel pellet temperatures being predicted and reduced initial fuel pellet stored energy. However, for SBLOCAs, the time of PCT is much later than for LBLOCAs, so the initial stored energy has already been transferred to the reactor coolant. As a result, the initial fuel pellet temperature distribution did not affect SBLOCA PCT.

5) Liquid entrainment under-predicted in the steam generator tubes

The LBLOCA methodology uses a bias on interphase friction at the steam generator tube sheet entrance to establish the magnitude of liquid entrainment in the steam generator tubes. The amount of liquid entrainment was found to be under-predicted due to a low value being specified for the interphase friction multiplier in the evaluation model.

During the reflood phase of a LBLOCA, some of the water droplets entrained in the flow from the core region are vaporized in the steam generator tubes due to heat transfer from the hot secondary side of the steam generator. The vaporization of the water in the steam generator tubes increases the pressure difference between the break and the core, typically called "steam binding," which affects the rate of core flooding and consequently PCT.

The interphase friction multiplier was increased as described in AREVA calculation E-2353-N90-59, "Evaluation of Interfacial Drag between Phases for UPTF and FLECHT-SEASET Tests." Sensitivity studies with the higher value for the interphase friction multiplier determined a bounding 12 °F increase in LBLOCA PCT.

In a SBLOCA event, depressurization of the RCS is much slower and break flows are less. The only time the interphase friction occurs in the hot legs and steam generator inlet plenums tube regions is during the reflux condensation period when the flow at the tube inlet is counter-current. The flow at the tube inlet is primarily controlled by counter-current limitations. Therefore, interphase friction and the amount of water retained in the steam generator tubes does not affect SBLOCA PCT results, and the modeling of this phenomenon is not part of the SBLOCA methodology.

6) High head ECCS injection delay time increase

The ECCS flow to the RCS cold legs from the high head ECCS pumps is modeled in the LBLOCA and SBLOCA analyses as starting after the injection isolation valves are fully open. The motor operator on these injection isolation valves has been modified, resulting in an increase in their opening time. The SBLOCA analysis uses a very long delay time for high head ECCS pump injection, so the longer opening time on the injection isolation valves did not result in an increase in the assumed delay time. However, the LBLOCA analysis required an increase in the high head ECCS pump injection time delay. The longer delay time for the high head ECCS pump injection reduces the initial volume of water available for core cooling, and resulted in a 24 °F increase in LBLOCA PCT.

7) Upper plenum modeling inhibits vapor flow into the top of the hot bundle

During the reflood phase of a LBLOCA, steam velocities in the hotter fuel assembly flow channels could prevent water above the core from draining back and quenching the hotter fuel pins. To ensure top-down quench does not occur, the LBLOCA modeling of the upper plenum was revised to not allow the core to be quenched from ECCS flow that enters from above the core. The nodalization of the upper plenum was revised and a high (reverse) loss coefficient was used to prevent water from flowing back into the core from the upper plenum. Subsequent analyses determined that there was no change in LBLOCA PCT.

In a SBLOCA, the flows between the upper plenum and the core have less of an effect on core cooling, as the core remains substantially covered, so much less steam is produced during the quenching of the core. That is, steam flow in the hot channel would not be high enough to prevent water in the upper plenum from draining back to the core. In addition, for a SBLOCA, the quenching of the core always occurs from the bottom of the core upwards, so SBLOCA PCT was unaffected.