TVA

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10 CFR 50.4
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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 - Combined Annual and 30-Day Report for Sequoyah Nuclear Plant, Units 1 and 2**

References:
1. Letter from NRC to TVA, "Sequoyah Nuclear Plant, Units 1 and 2 - Issuance of Amendments to Revise the Technical Specification to Allow Use of AREVA Advanced W17 High Thermal Performance Fuel (TS-SQN-2011-07) (TAC Nos. ME6538 and ME6539)," dated September 26, 2012 [ML12249A394, ML12249A415]
2. TVA Letter to NRC, "10 CFR 50.46 - 30-Day Special Report," dated September 20, 2013 [ML13269A377]
3. TVA Letter to NRC, "10 CFR 50.46 - 30-Day Special Report for Sequoyah Nuclear Plant, Unit 2, dated January 31, 2013 [ML13037A106]

The purpose of this letter is to provide the annual report of the changes to the calculated peak cladding temperature (PCT) for the Sequoyah Nuclear Plant (SQN), Units 1 and 2, Emergency Core Cooling System (ECCS) evaluation models in accordance with Title 10 of the Code of Federal Regulations (10 CFR) 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," paragraph (a)(3)(ii). This report also serves as the 30-day report of the changes to the PCTs for SQN, Unit 1, involved with the adoption of new ECCS Analyses of Record (AORs) as part of the implementation of License Amendment No. 331 (Reference 1). The amendment was implemented on October 25, 2013. As such, in addition to satisfying the annual reporting requirements of 10 CFR 50.46(a)(3)(ii) for SQN, Units 1 and 2, this submittal also satisfies the 30-day reporting requirement for Unit 1.

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The enclosed report provides a summary of the changes to the calculated PCTs for the limiting ECCS analyses applicable to SQN, Units 1 and 2, that were made since submittal of the Reference 2 and 3 reports, respectively.

As indicated in the enclosed report, the identified PCT changes for SQN, Unit 1, exceed the 50 degrees Fahrenheit (°F) threshold for a significant change or error as defined in 10 CFR 50.46(a)(3)(i). Accordingly, any subsequently discovered change or error would be considered significant for the purposes of reporting until such time as a reanalysis of the ECCS evaluation model is completed. As described in the enclosed report, the reported changes include model reanalyses. Therefore, the cumulative sums of the absolute magnitudes of the PCT changes for Unit 1 have been restored to zero for 10 CFR 50.46(a)(3)(ii) reporting purposes, with the subsequent changes and errors that affect PCT reflected in Table 2 of the enclosed report.

Compliance with the 10 CFR 50.46 requirements is demonstrated by the calculated Large Break Loss of Coolant Accident (LBLOCA) and Small Break Loss of Coolant Accident (SBLOCA) PCTs for SQN, Units 1 and 2, remaining below the 2200°F limit. For both Units 1 and 2, as presented in the enclosed report, the current updated (net) licensing basis PCT for the ECCS LBLOCA is 1940°F and the current updated (net) licensing basis PCT for the SBLOCA is 1470°F. Accordingly, no further actions are required.

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

Respectfully,

J.W. Shea
Vice President, Nuclear Licensing

Enclosure:

10 CFR 50.46 Annual and 30-Day Report of Peak Cladding Temperature Changes

cc (Enclosure):

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

ENCLOSURE

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

10 CFR 50.46 ANNUAL AND 30-DAY REPORT OF PEAK CLADDING TEMPERATURE CHANGES

At the completion of the recent Unit 1 Cycle 19 Refueling Outage, both reactor cores at the Sequoyah Nuclear Plant (SQN) will contain both AREVA Advanced W17 High Thermal Performance (HTP) and the AREVA Mark BW fuel assembly designs. In accordance with the reporting requirements of 10 CFR 50.46(a)(3)(ii), the following is a summary of the effects of the recent use of AREVA HTP fuel on the limiting design basis Loss of Coolant Accident (LOCA) analysis results established using new SQN Emergency Core Cooling System (ECCS) evaluation model Analyses of Record (AORs).

The revised topical reports used for the Large Break LOCA (LBLOCA) and Small Break LOCA (SBLOCA) evaluations are listed in the administrative section of the SQN, Units 1 and 2, Technical Specifications (TSs) as approved Core Operating Limits Report methods:

1. The LBLOCA evaluation methodology is based on EMF-2103P-A, Revision 0, with plant specific Topical Report ANP-2970(P), Revision 0, that incorporate the AREVA HTP fuel assembly design. Topical Report ANP-2970(P) also incorporates TVA's and AREVA's response to an NRC Request for Additional Information (RAI), which is documented in ANP-2970Q1(P), Revision 0.

2. The SBLOCA evaluation methodology is based on EMF-2328(P)(A), Revision 0, that uses S-RELAP5. Plant Specific Topical Report ANP-2971(P), Revision 1, incorporates the AREVA HTP fuel assembly design into the SBLOCA analyses.

The current SQN, Units 1 and 2, AORs for the AREVA W17 Advanced HTP fuel design are detailed in Topical Reports ANP-2970(P) and ANP-2970Q1(P), "Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis," and ANP-2971(P), "Sequoyah Units 1 and 2 HTP Fuel S-RELAP5 Small Break LOCA Analysis." These reports were submitted to the Nuclear Regulatory Commission (NRC) as part of SQN TS Change TS-SQN-2011-07 to modify the TSs to allow the use of AREVA Advanced W17 HTP fuel assemblies. The TS change associated with the AREVA HTP fuel design and supporting documentation were reviewed and approved as documented in the NRC Safety Evaluation Report dated September 26, 2012 [ADAMS Accession No. ML12249A415].

Table 1 details the changes to the PCTs for SQN, Unit 1, through the end of Unit 1 Cycle 19. This table is unchanged from the 30-day report submitted on September 20, 2013 (Reference 2 of cover letter).

Table 2 details the PCT changes that are applicable to the current AORs for AREVA HTP fuel in SQN, Units 1 and 2.

The PCT changes since the previous 10 CFR 50.46 report for Unit 1 (Reference 2 of cover letter) can be summarized as:

- The LBLOCA PCT for SQN, Unit 1, increased by 165°F and results in a current net licensing basis PCT of 1940°F. This change is due to implementation of the new AOR for AREVA HTP fuel and subsequent errors discovered in that AOR.

- The SBLOCA for SQN, Unit 1, increased by 67°F and results in a net current licensing basis PCT of 1470 °F. This change is due to implementation of the new AOR for AREVA HTP fuel.

The total PCT changes listed above were determined using the data contained in Tables 1 and 2. A 30-day report is required for SQN, Unit 1, because the absolute magnitudes of the cumulative PCT changes relative to the previous AOR for both the LBLOCA and SBLOCA exceed 50°F.

The PCT changes since the previous 10 CFR 50.46 report for Unit 2 (Reference 3 of cover letter) can be summarized as:

- The LBLOCA PCT for SQN, Unit 2, decreased by 10°F and results in a current net licensing basis PCT of 1940°F.

- The SBLOCA for SQN, Unit 2, remains unchanged from the AOR, with a net licensing basis PCT of 1470°F.

As listed in Table 2, based on the current AOR for both SQN units, the cumulative sum of the absolute magnitudes of the LBLOCA PCT changes is 10°F. No changes or errors to the current SBLOCA AOR have been reported. For future 10 CFR 50.46 reports, only the Table 2 data, which are representative of the current AORs, will be updated.

TABLE 1

Summary of SQN, Unit 1, PCT Changes Through End of Cycle 19

Report Year	Description	LBLOCA PCT (°F)	Change in LBLOCA PCT (°F)	SBLOCA PCT (°F)	Change in SBLOCA PCT (°F)	Notes
2008	**AOR PCT (previous)**	**1809**	-------	**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	-------	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	S-RELAP5 Sleicher-Rouse heat transfer correlation equation error	-------	-35	-------	0	8
2012	Non-conservative liquid fallback into surrounding six (6) assemblies	-------	0	-------	0	9
2013	Cathcart-Pawel uncertainty correlation error in RLBLOCA applications	-------	0	-------	0	10
2013	RODEX3a error in treatment of “trapped stack” condition	-------	-10	-------	0	11

TABLE 1 (Continued)

Summary of SQN, Unit 1, PCT Changes Through End of Cycle 19

Report Year	Description	LBLOCA PCT (°F)	Change in LBLOCA PCT (°F)	SBLOCA PCT (°F)	Change in SBLOCA PCT (°F)	Notes
2013	**Updated Licensing Net PCT** $AOR\ PCT + \sum \Delta\ PCT$	**1775**	**-34**	**1403**	**0**	-------
	Cumulative sum of PCT changes $\sum \lvert \Delta\ PCT \rvert$	-------	**116**	-------	**0**	-------

TABLE 2

Summary of SQN, Units 1 and 2, PCT Changes for AREVA HTP Fuel AORs

Report Year	Description	LBLOCA PCT (°F)	Change in LBLOCA PCT (°F)	SBLOCA PCT (°F)	Change in SBLOCA PCT (°F)	Notes
2013	New AORs for AREVA HTP fuel: ANP-2970(P) Rev. 0, ANP-2970Q1(P), Rev. 0, and ANP-2971(P), Rev. 1	**1950**	-------	**1470**	-------	12
2013	Cathcart-Pawel uncertainty correlation error in RLBLOCA applications	-------	0	-------	0	10
2013	RODEX3a error in treatment of "trapped stack" condition	-------	-10	-------	0	11
2013	**Updated Licensing Net PCT** $AOR\ PCT + \sum \Delta\ PCT$	**1940**	**-10**	**1470**	**0**	-------
	Cumulative sum of PCT changes $\sum \lvert \Delta\ PCT \rvert$	-------	**10**	-------	**0**	-------

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 effect on PCT based on the time that PCT occurs. For SQN, Unit 1, PCT occurs during blowdown (less than 100 seconds), which resulted in no change in PCT from the higher initial fuel pellet temperatures. For SQN, Unit 1, PCT occurs during blowdown (less than 100 seconds), which resulted in no change 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.

8) S-RELAP5 Sleicher-Rouse heat transfer correlation equation error

Sleicher-Rouse is one of the correlations used in the S-RELAP computer code for predicting convective heat transfer between the fuel and coolant single-phase vapor. This correlation is applicable to both the LBLOCA and SBLOCA analyses performed with S-RELAP5. During a review of the behavior of the Sleicher-Rouse correlation relative to other single-phase vapor heat transfer correlations, an error was discovered in the form of the correlation used in the S-RELAP5 implementation. The difference is related to the form of the equation for calculating the exponent of the temperature ratio correction term. The S-RELAP form of the Sleicher-Rouse heat transfer correlation has been updated to:

$$n = -[\log 10(Tw/Tg)]^{1/4} + 0.3$$

This correction resulted in a 35°F decrease in LBLOCA PCT for SQN Units 1 and 2. There was no change in SBLOCA PCT.

9) Non-conservative liquid fallback into surrounding six (6) assemblies

During the reflood phase of a LBLOCA, steam velocities in the central core region could prevent water above the core from draining back and quenching the fuel pins. Therefore, the LBLOCA evaluation model should not allow the fuel pins to be quenched from water that enters the fuel assemblies from above the core. Preventing water from flowing back into the core from the upper plenum is accomplished by applying a high reverse form loss coefficient (FLC) to the flow paths between the hot assembly and central core with the upper plenum.

The evaluation model was found not to include the above described high reverse FLCs in the central core region flow paths. However, a subsequent review of the LBLOCA cases in the AOR determined that no water entered the fuel assemblies in the central core region from above the core, so there was no increase in PCT resulting from this error.

There was no effect on the SBLOCA PCT for the same reasons as stated in Note 7 (above).

10) Cathcart-Pawel uncertainty correlation error in RLBLOCA applications

For Realistic LBLOCA (RLBLOCA) analyses, the rate-dependent correlation developed by Cathcart-Pawel is used to model the metal-water reaction during a LOCA. The rate constants for the Cathcart-Pawel equation are determined experimentally and the data are subjected to a statistical analysis to determine the relevant uncertainty parameters for the derived correlation. The RLBLOCA analysis uses a log-normal function for the uncertainty multiplier applied to the rate constant. The formula and standard deviation were found to be incorrect.

Analysis of the error confirmed that the effect on previous RLBLOCA analyses was negligible. There is no change to the LBLOCA PCT value for SQN, Units 1 and 2, from this error. This error did not apply to the SBLOCA analysis and, therefore, had no effect on the SBLOCA PCT value.

This error applies to both the 2008 LBLOCA analysis and the AREVA HTP LBLOCA analysis; therefore, it is reported in both Table 1 and Table 2.

11) RODEX3a error in treatment of "trapped stack" condition

A "trapped stack" condition exists when any fuel rod contains a gap dimension that is calculated to be less than 0.5 mil with open gaps lying at lower axial levels. If this condition exists, then a trapped stack model is intended to be applied. However, a coding error was identified which essentially deactivated the trapped stack model. Although the effect of this error is small, it was determined that it could be conservative or non-conservative depending on the steady-state initial stored energy.

A development version of S-RELAP5 was prepared with the correct evaluation of the trapped stack model, and several code validation and plant sample problems were repeated. Analysis of the identified coding error using this updated version of S-RELAP5 determined that it was conservative for SQN and resulted in a 10°F reduction in PCT for the LBLOCA. This error is not applicable to the SBLOCA analysis as it uses RODEX2 and not RODEX3a.

This error applies to both the 2008 LBLOCA analysis and the AREVA HTP LBLOCA analysis; therefore, it is reported in both Table 1 and Table 2.

12) New AOR ECCS PCT associated with the use of AREVA W17 HTP Fuel at SQN

The current SQN, Units 1 and 2, AORs for the AREVA W17 Advanced HTP fuel design are detailed in Topical Reports ANP-2970(P) and ANP-2970Q1(P), "Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis," and ANP-2971(P), "Sequoyah Units 1 and 2 HTP Fuel S-RELAP5 Small Break LOCA Analysis." These new AORs constitute a reanalysis of the ECCS evaluation models. As such, the cumulative sums of the absolute magnitudes of the PCT changes for both units have been restored to zero for 10 CFR 50.46(a)(3)(ii) reporting purposes.

The subsequent changes and errors that affect PCT are reported in Table 2 of this report, with the applicable discussion notes indicated.