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January 8, 2007

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Subject: Duke Power Company LLC d/b/a Duke Energy Carolinas, LLC (Duke)

Catawba Nuclear Station, Units 1 and 2
Docket Nos. 50-413 and 50-414

McGuire Nuclear Station, Units 1 and 2
Docket Nos. 50-369 and 50-370

Oconee Nuclear Station, Units 1, 2, and 3
Docket Nos. 50-269, 50-270, and 50-287

Evaluation Results Confirming Existing Boron Precipitation Analyses of Record Have Sufficient Margin and Remain in Compliance with the Regulations and Plant Design Basis.

Reference: NRC letter dated November 23, 2005, D.S. Collins to G. C. Bischoff, "Suspension of NRC Approval for Use of Westinghouse Topical Report CENPD-254-P, Post LOCA Long Term Cooling Model, Due to Discovery of Non-Conservative Modeling Assumptions During Calculation Audit".

The purpose of this letter is to respond to the reference cited above requesting a written response to concerns associated post-LOCA long-term cooling models, specifically those dealing with precluding boron precipitation. Specifically, the reference above requested that licensees who have relied on CENPD-254-P or similar analytical models perform an evaluation to confirm that sufficient margin

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exists in the analyses of record, and that analysis of record remains in compliance with the regulations and plant design basis. Duke reactors do not rely on the methodology outlined in CENPD-254-P, but Duke employs similar analytical models in the current licensing basis with respect to boron precipitation.

The attached report contains a summary of the existing calculations with respect to the post-LOCA boric acid precipitation issues identified by the NRC. A review of these calculations, and subsequent confirmatory analysis for McGuire and Catawba, concluded that sufficient margin exists in the methodology and assumptions to prevent the boric acid concentration in the reactor core from exceeding the solubility limit following a LOCA. The review of the Oconee analysis-of-record showed sufficient margin exists without any additional confirmatory analysis.

There are no regulatory commitments contained in this letter or attachment.

Please contact George Strickland at 803-831-3585 with any questions or comments.

Sincerely,

J. R. Morris

Attachment

xc (with attachment):

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DUKE RESPONSE TO NRC REQUEST FOR JUSTIFICATION OF CURRENT OPERATION FOR POST-LOCA BORIC ACID PRECIPITATION ISSUES

The NRC issued Reference 1 on November 23, 2005 to the Westinghouse Owners Group with a request that licensees perform an evaluation to confirm that sufficient margin exists in their boron precipitation analyses. Reference 1 followed Reference 2, an August 1, 2005 letter from the NRC notifying Westinghouse of their suspension of approval of the post-LOCA long-term cooling model due to non-conservative modeling assumptions. Reference 2 delineated 15 modeling concerns, of which these were condensed into four primary concerns in Reference 1. The Pressurized Water Reactors Owners Group (PWROG) responded in Reference 3 to the four concerns outlined in Reference 1 on behalf of most PWRs in the nuclear industry. Since Duke performs the boron precipitation analyses of record (AOR) for the Duke reactors, the response contained herein is being issued as confirmation to the NRC that sufficient margin exists in the boron precipitation AOR for the McGuire, Catawba, and Oconee Nuclear Stations. As explained below, confirmatory analyses were needed to demonstrate sufficient margin exists in the McGuire/Catawba AOR, but no confirmatory analyses were needed to address the Oconee AOR.

Specifically in Reference 1, the NRC staff wanted the following four concerns to be addressed in a confirmatory evaluation for each PWR:

1. The effective mixing volume must be justified and the void fraction must be taken into account. However, a larger effective mixing volume consisting of part of the lower plenum may be used with sufficient justification.

2. The effective mixing volume will vary as a function of time, and this variation must be taken into account while considering the pressure drop in the loop.

3. The boron solubility limit must be justified, especially if containment pressures above 14.7 psia or sump water additives are credited.

4. If using a 10CFR50 Appendix K model, the decay heat multiplier must be 1.2 for all times assuming an infinite operating history. If using a non-Appendix K model, a realistic decay heat multiplier may be used with sufficient justification.

The PWROG response in Reference 3 also offered some clarifications to the Reference 1 letter from the NRC. The clarifications applicable to the Duke reactors are as follows:

1. The margin of safety to core cooling is the requirement to be considered in the assessment.

2. The reasonable amount of time period (i.e., 90 days) identified by the NRC is not a requirement. Flexibility in the time period is acceptable.

3. The NRC does not expect a new quantitative analysis of boric acid precipitation as was done for Waterford 3. A qualitative assessment of margin for continued operation is acceptable. The NRC does not request a change to the plant design or licensing basis at this time.

4. A high level assessment for the Reasonable Assurance of Safe Operation is acceptable provided it includes a qualitative assessment of margin in the individual plant analyses.

5. The NRC clarified that issues 1-3 on the second page of Reference 1 need to be considered in the qualitative assessment of margins. Insights from the Waterford 3 analysis and compensating margins of items 1-3 on the first page of Reference 1 should be considered.

6. All four issues on the second page of the Reference 1 letter need to be addressed by licensees on any future license amendments.

The following table summarizes the results/assumptions in the existing AOR for the Duke reactors:

AOR Parameter	McGuire/Catawba (W 4-loop)	Oconee (B&W)
Operator Action Time	6 Hours	9 Hours
Core Voiding Included	Yes	No
Loop ΔP Effects Included	No	No
Boron Solubility Limit	< 23.53 wt%	< 23.53 wt%
Decay Heat Model	1979 ANS	1.2 x 1971 ANS
Lower Plenum Credit	None	None
Upper Plenum Credit	Below hot leg	Below hot leg

Sump Additive Credit	None	None
Containment Pressure Credit	None	None

The McGuire/Catawba AOR performed by Duke follows the Westinghouse methodology presented in Reference 4. Although Reference 4 contains calculations both with and without credit for the lower plenum volume, the McGuire/Catawba AOR does not credit any of the lower plenum volume. The McGuire/Catawba AOR also accounts for core voiding.

The Oconee AOR performed by Duke follows a plant-specific methodology described in Reference 5 that credits a conservative minimum flow through the reactor vessel internals vent valves (RVVVs). At Oconee, a natural circulation flow path from the core through the RVVVs to the downcomer exists during the initial long term phase of post-LOCA heat removal. This RVVV flow path has a significant beneficial impact on the calculated core boron concentration since it provides a circulation path that minimizes boron buildup in the core. When crediting this flow path in boron precipitation analyses, the assumption of high decay heat is actually non-conservative as higher decay heat promotes more flow through the core region, thus keeping the core boron concentration dilute. At some point in time, however, decay heat becomes insufficient to drive the liquid flow through the RVVVs. Therefore, the AOR for Oconee analyzes a range of decay heat multipliers (up to 1.2) using decay heat dependent RVVV flows calculated using the BFLOW code methodology described in Reference 6. The BFLOW code is used to calculate long-term liquid and steam mass flow rates following a large cold leg break at Oconee. Although the BFLOW code accounts for void fraction axially, the mixing volume assumed in the Oconee AOR corresponds to zero void fraction. However, no confirmatory analyses are performed for Oconee since the resulting boron concentration in the AOR at 9 hours is less than half of the boron solubility limit (i.e., sufficient margin exists).

A summary table for the McGuire/Catawba confirmatory analyses is presented below, followed by a discussion of each of the NRC's four concerns presented in Reference 1.

Confirmatory Analysis	McGuire/Catawba (W 4-loop)
Operator Action Time	>7 Hours
Core Voiding Included	Yes
Loop ΔP Effects Included	Yes (but in a separate evaluation)
Boron Solubility Limit	< 23.53 wt%
Decay Heat Model	1.2 x 1971 ANS
Lower Plenum Credit	50%
Upper Plenum Credit	Below hot leg
Sump Additive Credit	None
Containment Pressure Credit	None

Issue #1: Effective Mixing Volume Calculation

The effective mixing volume calculated in the McGuire/Catawba AOR conservatively accounted for only the core volume and the portion of the upper plenum not exceeding the bottom of the hot legs (i.e., no credit for the lower plenum). In addition, the McGuire/Catawba AOR used a 30% void fraction assumption from the Westinghouse methodology (Reference 4), which was selected to bound the void fraction corresponding to a 24 hour switchover time. Since McGuire and Catawba employ a hot leg switchover time of six hours, a more conservative void fraction of 50% is assumed in the confirmatory analysis.

The NRC staff review of mixing volume assumptions on page 151 of Reference 7 for the Waterford-3 extended power uprate (EPU) states the following:

> "The mixing volume was increased to also include 50% of the lower plenum. The Mitsubishi Heavy Industries' BACCHUS test facility employed to simulate post-LOCA boric acid mixing in the lower plenum and core of a Westinghouse and CE-designed PWR was cited as justification for expanding the mixing volume to also include a portion of the lower plenum. The tests … showed that the entire lower plenum volume contributed to the mixing. Hence crediting only 50 percent of this volume is conservative."

Similarly, the mixing volume in the McGuire/Catawba confirmatory analysis was increased to include 50% of the lower plenum, consistent with the Westinghouse position in Reference 3.

Issue #2: Variable Mixing Volume (Increases with Time)

Statically modeling a conservatively small effective mixing volume and assuming a conservatively large void fraction is sufficient to confirm that boron precipitation does not occur at the six hour switchover time. However, this issue appears to be concerned only with the first hour of the transient as explained in the initial letter from the NRC to Westinghouse (Reference 2):

> "During early reflood and for the first hour in many designs, the two-phase (entrainment level) will remain below the top of the core with a two-phase mixture below a dispersed region consisting of steam and entrained droplets. The core remains cooled, however, the mixing volume would not include the upper plenum nor hot-sides until the loop resistance decreases sufficiently to allow the fluid to grow into these regions."

Based on the above, it is understood that the concern with respect to a variable mixing volume is near the beginning of the transient, not at the time of switchover to hot leg recirculation. As decay heat decreases, the liquid level rises, or swells, into the upper plenum area. While modeling the effects of any loop resistances during this early portion of the transient would retard the liquid level from rising, modeling these same effects would also increase the saturation temperature of the mixing volume due to the pressure increase (thereby adding more margin to the boron solubility limit). Figure I in Reference 4 shows that the solubility limit between 212°F and 250°F is linear, with corresponding saturation pressures of 14.7 and 29.8 psia from the steam tables, respectively. Figure I of Reference 4 also indicates solubility limits of roughly 27.5 and 42.5 wt% exists for 14.7 and 29.8 psia, respectively. Therefore, it can be correlated for this range of temperatures that each psi of pressure increase will increase the boron solubility limit by 1 wt%. Although not proven quantitatively, the expectation is that modeling the loop pressure drop effects in the early portion of the transient is more than offset by ignoring these same loop pressure drop effects on the boron solubility limit.

In addition, Duke performed a separate calculation assuming a mixing volume corresponding to the initial reflood phase that bounds the collapsed liquid levels observed in the current McGuire/Catawba LBLOCA analyses. At 1 hour, the result was that the boron concentration was half of that necessary to precipitate. Therefore, it is concluded that it is not possible to obtain boric acid concentrations of concern within the first hour of the event.

Issue #3: Boron Solubility Limit

The McGuire/Catawba AOR already conservatively assumes the previously established NRC limit of 4% less than the solubility limit of boric acid at 212°F (27.53 wt % minus 4 wt % equals 23.53 wt %). The confirmatory analysis continued with this very conservative assumption. However, it is possible to justify a higher boron solubility limit in future analyses by crediting containment additives designed to control sump pH levels during an accident.

Specifically at McGuire and Catawba, the sump water pH is increased by melting ice, which is a solution of sodium tetraborate. A study of the effect of the melting ice on boric acid precipitation for McGuire and Catawba was recently performed by Duke. This study concluded that the solubility limit of the sump water mixture would increase by a factor of roughly 1.75, which means that the current boron solubility limit of 23.53 wt% would increase to just over 44 wt% (27.53 wt % x 1.75 minus 4 wt %). While the results of this study are preliminary in nature, the results are consistent with the solubility limit increase to 36 wt% for Waterford-3 (Reference 7). While the Waterford-3 containment uses a different containment additive (trisodium phosphate), any pH control additive will increase the boron solubility limit.

Issue #4: Decay Heat Assumption

The McGuire/Catawba AOR uses the 1979 ANS decay heat standard with no uncertainties applied. The practice of applying no uncertainties is consistent with the methodology established in Reference 4.

It should be noted that McGuire and Catawba LBLOCA analyses use the Westinghouse best-estimate LOCA evaluation method, meaning a non-Appendix K decay heat model with a realistic decay heat multiplier could be justified for the confirmatory analysis. However, to ensure a conservative result, the Appendix K decay heat of 1.2 times the 1971 ANS decay heat standard with infinite operating history and heavy element decay was assumed in the confirmatory analysis.

Conclusions

The confirmatory analysis discussed above is identical to the AOR for McGuire/Catawba, except as follows: (1) an increased void fraction assumption of 50% (previously 30%) was assumed, (2) a credit for half of the lower plenum in the calculation of the effective mixing volume (previously no credit) was assumed, and (3) an increased decay heat assumption of 1.2 times the 1971 ANS decay heat standard with infinite operating history and heavy element decay was assumed.

The resulting time required for boron precipitation to occur, even with the conservative assumptions outlined in the preceding pages, still exceeded 7 hours. Given that the current hot leg switchover time is 6 hours at McGuire/Catawba, this confirmatory analysis demonstrates that the McGuire/Catawba AOR has sufficient margin and remains in compliance with NRC regulations and the McGuire/Catawba design bases for long term cooling. Again, no confirmatory analyses are necessary for Oconee due to current assumptions in the AOR.

Additionally, Reference 3 also includes a very detailed discussion of the safety significance of the potential for boric acid precipitation following a LOCA. The discussions presented therein are also applicable to the McGuire/Catawba and Oconee reactors.

References

1. Letter from Daniel S. Collins (NRC) to Gordon Bischoff (WOG) dated November 23, 2005. Suspension of NRC Approval for Use of Westinghouse Topical Report CENPD-254-P, "Post-LOCA Long-Term Cooling Model," Due to Discovery of Non-Conservative Modeling Assumptions During Calculations Audit (TAC No. MB1365).

2. Letter from Robert A. Gramm (NRC) to James A. Gresham (Westinghouse) dated August 1, 2005. Suspension of NRC Approval for Use of Westinghouse Topical Report

CENPD-254-P, "Post-LOCA Long-Term Cooling Model," Due to Discovery of Non-Conservative Modeling Assumptions During Calculations Audit.

3. Letter from Frederick P. Schiffley, III (PWROG) to Daniel S. Collins (NRC) dated June 19, 2006. Suspension of NRC Approval for Use of Westinghouse Topical Report CENPD-254-P, Post LOCA Long Term Cooling Model, Due to Discovery of Non-Conservative Modeling Assumptions During Calculation Audit, PA-ASC-0290.

4. Letter from C. L. Caso (Westinghouse) to T. N. Novak (NRC), File CLC-NS-309. Long Term Core Cooling - Boron Considerations. April 1, 1975.

5. Oconee Updated Final Safety Analysis Report (UFSAR), Section 6.3.3.2.1. Revision 15 Issued 6/30/06.

6. DPC-NE-3003-PA, Revision 1. Mass and Energy Release and Containment Response Methodology. September 2004.

7. Letter from N. Kalyanam (NRC) to Joseph E. Venable (Entergy) dated April 15, 2005. Waterford Steam Electric Station, Unit 3 - Issuance of Amendment RE: Extended Power Uprate (TAC NO. MC1355).