ATTACHMENT 18

Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3

Technical Specifications (TS) Change 478

Addition of Analytical Methodologies to Technical Specification 5.6.5.b for Browns Ferry 1, 2, & 3, and Revision of Technical Specification 2.1.1.2 for Browns Ferry Unit 2, in Support of ATRIUM-10 XM Fuel Use at Browns Ferry

ANP-2860 Revision 2 Supplement 1
Summary of Responses to Request for Additional Information
Extension to ATRIUM 10XM
(Non-Proprietary)

Attached is the non proprietary version of a supplemental report prepared by AREVA addressing RAIs from document ANP-2860NP Revision 2 whose answers would have a fuel type dependency. ANP-2860NP Revision 2 was docketed as part of TS-473, and was based on the ATRIUM-10 fuel type. The RAIs included in ANP-2860NP Revision 2 Supplement 1NP have been answered again based on XM fuel usage.

ANP-2860NP
Revision 2

Browns Ferry Unit 1 - Summary of Responses to Request for Additional Information

Supplement 1NP
Revision 0

Extension for ATRIUM 10XM

November 2012

AREVA NP Inc.

AREVA

AREVA NP Inc.

ANP-2860NP
Revision 2
Supplement 1NP
Revision 0

Browns Ferry Unit 1 - Summary of Responses to Request for Additional Information

Extension for ATRIUM 10XM

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Revision 0

Nature of Changes

Item	Page	Description and Justification
1.	All	New document

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Tables

Figures

1.0 Introduction

The purpose of ANP-2860P Revision 2 (Reference 1) was to present a summary of responses to NRC Requests for Additional Information supporting the use of the AREVA ATRIUM-10 fuel design in the three Browns Ferry Units (1, 2 and 3) with or without Extended Power Uprate. This reference report focused primarily on supplemental information on codes and methods used in licensing applications. The purpose of this supplement is to provide additional information to support the introduction of the ATRIUM 10XM fuel design and therefore addresses those topics in Reference 1 that are fuel design dependent.

Reference 1 was screened against the following criteria in the preparation of this supplement:

- Discussion is equally applicable to the ATRIUM10 and ATRIUM 10XM fuel designs
- Discussion is EPU-specific
- Discussion is methods-specific and the new method is part of the ATRIUM 10XM transition LAR review (e.g., SAFLIM 3D, RODEX4, ACE)
- RAIs associated with emergent issues will be addressed in RAIs related to the Browns Ferry license amendment request, consistent with Reference 6

Topics that were screened as meeting these criteria are not included in this supplement; topics that did not meet these criteria were determined to be ATRIUM 10XM-specific and are included in this supplement. Additionally, RAIs associated with the transition to the ATRIUM 10XM at Brunswick were reviewed against the above criteria and all RAIs screened out.

2.0 Thermal Hydraulics

2.1 *Void Quality Applicability*

The [ ] void-quality correlation has been qualified by AREVA NP against both the FRIGG void measurements and ATRIUM-10 measurements. A discussion can be found in Section 5.1 of Reference 1 on the applicability of the [ ] correlation.

The ATRIUM 10XM was tested in the KATHY test loop and void fraction measurements were taken, and the [ ] correlation was assessed against these measurements. The objective of the test campaign was to confirm the applicability of the correlation at high void fractions and to demonstrate that there is no bias associated with fuel designs.

2.2 *ATRIUM 10XM Void Fraction Measurements*

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2.2.1 Method

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2.2.2 Apparatus Description

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2.2.3 Measurement Technique

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2.2.4 Conclusion

The void correlation has been validated against measured ATRIUM 10XM void fractions up to [ ]. The comparison shows that the standard deviation between calculated and measured values is [ ] for the ATRIUM 10XM. Figure 2-1 shows the predicted versus measured void fraction for the ATRIUM 10XM.

Figure 2-2 shows the entire validating void fraction dataset. No trends or biases are observed based on design or void fraction. A good agreement is achieved between predicted and measured void fraction. The [ ] correlation is deemed appropriate to predict void fraction.

2.3 *ACE/ATRIUM 10XM Critical Power Ratio Correlation*

The critical power ratio (CPR) correlation used in MICROBURN-B2, SAFLIM3D, RELAX, RAMONA5-FA, XCOBRA, and XCOBRA-T is based on the ACE/ATRIUM 10XM critical power correlation described in Reference 2. As with all AREVA correlations, the range of applicability is enforced in AREVA methods through automated bounds checking and corrective actions. The ATRIUM 10XM bounds checking is provided in Table 2-1. The ACE CPR correlation uses K-factor values to account for rod local peaking, rod location and bundle geometry effects. The K-factor methodology was modified in Reference 3 in response to deficiencies found in the axial averaging process. In addition, the additive constants were revised as a result of the change to the K-factor model.

The K-factor parameter is described in detail in Section 3.1 of Reference 3.

At the time of the creation of this document, Reference 3 had not yet been generically approved. Reference 4 presents the ACE/ATRIUM 10XM critical power correlation that will be used in licensing analyses for Browns Ferry Units 1, 2, and 3 in the interim. The correlation presented in Reference 4 is exactly the same as that presented in Reference 3.

2.4 *Loss Coefficients*

Wall friction and component loss coefficients were determined for Browns Ferry based on single-phase testing of a prototypic ATRIUM 10XM fuel assembly in the Portable Hydraulic Test Facility (PHTF). Prototypical fuel rods, spacer grids, flow channel, upper tie plate and lower tie plate were used in the testing. A description of the PHTF facility and an overview of the process for determining the component loss coefficients are described in Reference 5.

2.4.1 Spacer Pressure Drop Testing

The PHTF is used by AREVA NP to obtain single phase loss coefficients for the spacers. The friction factor correlation is a Reynolds depend function based on the Moody friction model and the measured surface roughness. The pressure drops across the spacers are measured in the PHTF for each new design. [

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The wall friction and component loss coefficients determined from the PHTF and utilized in Browns Ferry for the ATRIUM 10XM fuel design are provided in Table 2-2 . The values have been selected because they are representative of the hydraulic characteristics of actual ATRIUM 10XM fuel assemblies loaded into the reactor.

2.4.2 PHTF ATRIUM 10XM Based Spacer Loss Coefficients

The ATRIUM 10XM PHTF tests form the basis for the single phase loss coefficients currently used for design and licensing analyses supporting U.S. BWRs. PHTF data was reduced to determine single phase losses for the spacers in the [ ]

[

] of the bundle.

Assessments of the predicted pressure drop relative to measured single and two-phase pressure drop data from the KATHY facility confirmed the applicability of the [

] for reactor analyses.

Figure 2-3 shows measured versus the MICROBURN-B2 predicted pressure drop for a range of conditions. It includes single phase and two phase data and confirms the applicability of the thermal-hydraulic models to predict pressure drop for the ATRIUM 10XM design.

Table 2-1 ACE/ATRIUM 10XM Bounds Checking

Table 2-2 Hydraulic Characteristics of ATRIUM 10XM Fuel Assemblies

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Figure 2-1 Predicted versus Measured Void Fraction for the ATRIUM 10XM

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Figure 2-2 Overall Validating Void Fraction Dataset

Figure 2-3 Measured versus Predicted Bundle Pressure Drop

3.0 Transients and Accidents

3.1 *XCOBRA-T Case Specific Power Fractions*

In Reference 1, Section 4.2, sensitivity studies were performed to assess the adequacy of the default power deposition fractions used for the fuel rod, active channel coolant and the core bypass coolant. While these sensitivity studies showed no significant change in ΔCPR between the generic power fractions and the case specific values, AREVA NP committed to automating the transfer of the case-specific power fractions into XCOBRA-T such that the generic values would no longer be used. This automation has been completed and XCOBRA-T now uses the case-specific power deposition fractions.

3.2 *Void Quality Correlation Uncertainties*

The AREVA NP analyses methods and the correlations used by the methods are applicable for all AREVA designs in both pre-EPU and EPU conditions. The approach for addressing the void-quality correlation bias and uncertainties remains unchanged and is applicable for BFN operation with the ATRIUM 10XM fuel design.

The OLMCPR is determined based on the safety limit MCPR (SLMCPR) methodology and the transient analysis (ΔCPR) methodology. Void-quality correlation uncertainty is not a direct input to either of these methodologies; however, the impact of void-correlation uncertainty is inherently incorporated in both methodologies as discussed below.

The SLMCPR methodology explicitly considers important uncertainties in the Monte Carlo calculation performed to determine the number of rods in boiling transition. One of the uncertainties considered in the SLMCPR methodology is the bundle power uncertainty. This uncertainty is determined through comparison of calculated to measured core power distributions. Any miscalculation of void conditions will increase the error between the calculated and measured power distributions and be reflected in the bundle power uncertainty. Therefore, void-quality correlation uncertainty is an inherent component of the bundle power uncertainty used in the SLMCPR methodology.

The transient analysis methodology is not a statistical methodology and uncertainties are not directly input to the analyses. The transient analyses methodology is a deterministic, bounding approach that contains sufficient conservatism to offset uncertainties in individual phenomena. Conservatism is incorporated in the methodology in two ways: (1) computer code models are developed to produce conservative results on an integral basis relative to benchmark tests, and (2) important input parameters are biased in a conservative direction in licensing calculations.

The transient analyses methodology results in predicted power increases that are bounding relative to benchmark tests. In addition, for licensing calculations a 110% multiplier is applied to the calculated integral power to provide additional conservatism to offset uncertainties in the transient analyses methodology. Therefore, uncertainty in the void-quality correlation is inherently incorporated in the transient analysis methodology.

Based on the above discussions, the impact of void-quality correlation uncertainty is inherently incorporated in the analytical methods used to determine the OLMCPR. Biasing of important input parameters in licensing calculations provides additional conservatism in establishing the OLMCPR. No additional adjustments to the OLMCPR are required to address void-quality correlation uncertainty.

3.2.1 Assessment of the Void-Quality Correlation

Assessments of the void-quality correlation were reported in Reference 1 (Sections 6.7.1 through 6.7.5) to demonstrate that no additional adjustments to the OLMCPR are required to address void correlation uncertainty. With the ATRIUM 10XM void fraction benchmarks presented in Figure 2-1 and Figure 2-2, the applicability of the void-quality correlation at high void fractions is confirmed and the uncertainty associated with the application of the correlation to the ATRIUM 10XM design is demonstrated to be equivalent to the data used in Reference 1. Therefore, the sensitivity studies and conclusions drawn in Reference 1 are equally applicable to the ATRIUM 10XM applications at Browns Ferry.

4.0 ATWS

4.1 *ATWS General*

The COTRANSA2 computer code is the primary code used for the ATWS overpressurization analysis. The XCOBRA-T computer code is not used in the ATWS overpressurization analysis. The ATWS overpressurization event is not used to establish operating limits for critical power; therefore, the ACE/ATRIUM 10XM critical power correlation pressure limit is not a factor in the analysis.

Dryout conditions are not expected to occur for the core average channel that is modeled in COTRANSA2 for the ATWS overpressurization analysis. Dryout might occur in the limiting (high power) channels of the core during the ATWS event; however, these channels are not modeled in COTRANSA2 analyses. For the ATWS overpressurization analysis, ignoring dryout for the hot channels is conservative in that it maximizes the heat transferred to the coolant and results in a higher calculated pressure.

The ATWS event is not limiting relative to acceptance criteria identified in 10 CFR 50.46. The core remains covered and adequately cooled during the event. Following the initial power increase during the pressurization phase, the core returns to natural circulation conditions after the recirculation pumps trip and fuel cladding temperatures are maintained at acceptable low levels. The ATWS event is significantly less limiting than the loss of coolant accident relative to 10 CFR 50.46 acceptance criteria.

4.2 *Void Quality Correlation Bias*

AREVA NP performs cycle-specific ATWS analyses of the short-term reactor vessel peak pressure using the COTRANSA2 computer code. The ATWS peak pressure calculation is a core-wide pressurization event that is sensitive to similar phenomenon as other pressurization transients. Bundle design is included in the development of input for the coupled neutronic and thermal-hydraulic COTRANSA2 core model. Important inputs to the COTRANSA2 system model are biased in a conservative direction.

The AREVA NP transient analysis methodology is a deterministic, bounding approach that contains sufficient conservatism to offset biases and uncertainties in individual phenomena. As demonstrated in Section 2.2 the void-quality correlation is robust for past and present designs including the ATRIUM 10XM.

In Reference 1, Section 8.2 a sensitivity study was performed for the limiting ATWS pressurization event for a proposed BFN cycle with EPU to assess the bias between the ATRIUM-10 test data and the void-quality correlation. The event was a pressure regulator failure-open (PRFO), which is a depressurization event, followed by pressurization due to main steam line isolation valve (MSIV) closure. The neutronics input included the impact of the fuel depleted with changes in the void-quality correlation. To remove the bias in the MICROBURN-B2 neutronics input, the [ ] void-quality correlation was modified. To address the bias in the Ohkawa-Lahey void-quality correlation for the COTRANSA2 code, the void-quality relationship was changed to a [ ]. Additionally the sensitivity study was repeated without depleting the fuel with the changes in the void-quality correlation (the change in the void-quality correlation was instantaneous at the exposure of interest).

The reference ATWS case demonstrated the change in the void-quality correlations resulted in a 10-psi increase in the peak vessel pressure. The results for an instantaneous change in the void-quality correlation showed the same impact. A study was also performed for the ASME overpressure event (MSIV closure). The change in the void-quality correlations resulted in a 7-psi increase in the peak pressure.

While the impact of a change in the bias of the void-quality correlations on peak pressure is expected to be more than offset by the model conservatisms, AREVA NP entered the issue into their corrective action program and has imposed that a 10-psi increase to the peak vessel pressure for the ATWS overpressure analysis and a 7-psi increase to the peak vessel pressure for the ASME overpressure analysis be included in analyses results.

With the first introduction of the ATRIUM 10XM fuel design, similar sensitivity studies for the ATWS and ASME overpressure analysis were repeated with the same bias corrections and confirmed that the same penalties are applicable for the ATRIUM 10XM core designs. The pressure penalties are applied for the Browns Ferry analyses.

4.3 *ATWS Containment Heatup*

Fuel design differences may impact the power and pressure excursion experienced during the ATWS event. This in turn may impact the amount of steam discharged to the suppression pool and containment.

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Table 4-1 [

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5.0 Neutronics

From the neutronics perspective, the ATRIUM-10XM fuel design differs from the ATRIUM-10 fuel design primarily in the position and number of the part length rods. The neutronic models have already been demonstrated to accurately model the vacant positions and this continues to be true for the ATRIUM-10XM fuel design.

5.1 *Shutdown Margin*

The part length rod in the corner of the assembly improves the shutdown margin performance of the fuel design because of the flux trap that is created in the cold condition with the vacant rod position of all four assemblies in a control cell being in close proximity. The heterogeneous solution of CASMO-4 accurately models the vacant rod position and the associated reactivity. Operating experience with two reloads of ATRIUM-10XM fuel have demonstrated no change in predicted cold critical eigenvalue, as shown in Figure 5-1, such that the target eigenvalue is unchanged from previous operating history with the ATRIUM-10 fuel design.

5.2 *Monitoring*

The part length rod in the corner of the assembly has an impact on the corner flux that influences the detector response. The heterogeneous solution of CASMO-4 accurately calculates this corner flux depression. This characterization is used directly in the MICROBURN-B2 determination of the predicted detector response. For the Browns Ferry analyses the plena have been explicitly modeled with the heterogeneous CASMO-4 model, thus providing the most accurate model available.

5.3 *Power Distribution Uncertainty*

Operating experience with two reloads of ATRIUM-10XM fuel has demonstrated no significant change in the uncertainty of the predicted detector response relative to the measurements as demonstrated in Table 5-1 and Table 5-2. The ATRIUM-10XM cycles are highlighted in red font. The significant margins exhibited for BFN, shown in Section 7.3 of Reference 1, coupled with the relative insensitivity of the uncertainties to the change in fuel design demonstrated in

Table 5-1 and Table 5-2, give high confidence that the use of ATRIUM-10 XM fuel at BFN will be within the values assumed in the safety analyses.

5.4 *Bypass modeling*

The bypass behavior of the ATRIUM-10XM fuel design is identical to the ATRIUM-10 fuel design, thus there is no difference in the modeling. Any differences in bypass heat deposition are treated explicitly.

Table 5-1 TIP Statistics for Operating Cycles During the Transition from ATRIUM-10 to ATRIUM-10XM Fuel

Table 5-2 TIP Statistics for Operating Cycles During the Transition from ATRIUM-10 to ATRIUM-10XM Fuel

[ ]

Figure 5-1 Cold Critical Eigenvalue for Operating cycles during the transition from ATRIUM-10 to ATRIUM-10XM Fuel

6.0 References

1. ANP-2860P Revision 2, *Browns Ferry Unit 1 Summary of Responses to Request for Additional Information,* AREVA NP Inc., October 2009.

2. ANP-10298PA Revision 0, *ACE/ATRIUM 10XM Critical Power Correlation*, AREVA NP Inc., March 2010.

3. ANP-10298PA Revision 0, Supplement 1P Revision 0, *Improved K-Factor Model for ACE/ATRIUM 10XM Critical Power Correlation*, December 2011.

4. ANP-3140 Revision 0, *Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation,* AREVA NP Inc., August 2012.

5. I.K. Madni, et al., "Development of Correlations for Pressure Loss/Drop Coefficients Obtained From Flow Testing of Fuel Assemblies In Framatome ANP'S PHTF," Paper Number 22428, Proceedings of ICONE10, Arlington, VA, April 14-18,2002.

6. Proceedings of the 2012 Top Fuel Performance Meeting, Manchester, United Kingdom, September 2-6, 2012, "The U. S. Nuclear Regulatory Commission's Strategy for Revising the RIA Acceptance Criteria," Paul M. Clifford, Paper A0112.