

March 30, 2017

Mr. Gary Peters, Director  
Licensing and Regulatory Affairs  
AREVA Inc.  
3315 Old Forest Road  
Lynchburg, VA 24501

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: AREVA INC. TOPICAL REPORT BAW-10247P-A, SUPPLEMENT 2P, REVISION 0, "REALISTIC THERMAL-MECHANICAL FUEL ROD METHODOLOGY FOR BOILING WATER REACTORS SUPPLEMENT 2: MECHANICAL METHODS" (CAC NO. MF7708)

Dear Mr. Peters:

By letter dated April 29, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16124B057), AREVA Inc. (AREVA) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review and approval Topical Report BAW-10247P-A, Supplement 2P, Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods." Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. On January 11, 2017, Alan Meginnis, AREVA Product Licensing Manager, and I agreed that the NRC staff will receive the response to the enclosed request for additional information (RAI) questions within 60 days from the date of this letter.

If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-4053.

Sincerely,

*/RA/*

Jonathan G. Rowley, Project Manager  
Licensing Processes Branch  
Division of Policy and Rulemaking  
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure:  
RAI Questions (Non-Proprietary)

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: AREVA INC. TOPICAL REPORT BAW-10247P-A, SUPPLEMENT 2P, REVISION 0, "REALISTIC THERMAL-MECHANICAL FUEL ROD METHODOLOGY FOR BOILING WATER REACTORS SUPPLEMENT 2: MECHANICAL METHODS" (CAC NO. MF7708) DATED: MARCH 30, 2017

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**NRR-106**

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REQUEST FOR ADDITIONAL INFORMATION

RELATED TO TOPICAL REPORT BAW-10247P-A, SUPPLEMENT 2P, REVISION 0

“REALISTIC THERMAL-MECHANICAL FUEL ROD METHODOLOGY FOR BOILING WATER

REACTORS SUPPLEMENT 2: MECHANICAL METHODS”

AREVA INC.

(CAC NO. MF7708)

**RAI 1**

Regarding measurements supporting the rod-to-rod gap closure correlation, the topical report (TR) states that the fuel rod-to-rod gap measurements are generally performed at each span between spacer grids and for each gap. The text should be changed to indicate that each span and gap must be measured so that the correlation remains unbiased (i.e., not measuring each span and every gap could invalidate the derived 95/95 upper tolerance limit (UTL)). Revise the text describing the methodology or justify not doing so. Also, describe any changes to the measurement tool and techniques to acquire the rod bow data relative to XN-75-32(P)(A), Supplement 1.

**RAI 2**

The various models defined in Appendices A, B, and C of the TR are based on [ ]. However, Equation A-3 includes a [ ] of Reference A-1 in the TR. This table was not meant to be used for [ ]. Reference A-1, includes information for [ ]

Furthermore, use of statistical tolerance factors for a [ ], as discussed in Reference 1, assumes: (1) the random error follows a normal distribution with mean 0 and some standard deviation, and (2) the observations to be statistically independent of each other, i.e., the correlation of  $y_i$  and  $y_j$  for  $i$  not equal to  $j$  is zero. Looking at the data in Figure A-1, "[Boiling Water Reactor] BWR Fuel Rod Bow Correlation," it appears that the assumption of statistical independence is not valid as there are distinct clusters in the data marked by vertical lines. Furthermore, it is not clear that the random error follows a normal distribution. Consequently, use of the one-sided statistical tolerance factor as described in the TR does not appear to be justified.

- a. Update Equation A-3 based on the discussion above or explain why the model remains appropriate.
- b. Regarding Equation A-2, what are [ ] and [ ] defined as? An [ ] is specified but not used; update the equation accordingly.

Enclosure

- c. Similar to Part a., update Equation B-1 or explain why the model specified by Equation B-1 remains appropriate. Also note that Figure B-1, "BWR Fuel Rod Growth Correlation for [stress relief annealed] SRA Cladding," appears to show a [ ], and the tolerance factor used does not account for this. The U.S. Nuclear Regulatory Commission (NRC) staff notes that this may be caused by oversimplification of the model due to the lumping of subgroups into a single group.
- d. Similar to Part a., update Equation C-1 or explain why the model specified by Equation C-1 remains appropriate.
- e. The "s" term (i.e., the standard deviation) in Equations B-2 and C-2 are inconsistent with the analogous term used in the fuel rod bow model given in Equation A-2. Revise the "s" term in Equations B-2 and C-2 to be consistent with the [ ] in Equation A-2 or explain why using the standard deviation is appropriate.
- f. Provide the data supporting the fuel rod bow, fuel rod growth, and fuel assembly growth correlations in tabular format so that the NRC staff can perform confirmatory calculations to either verify the validity of: (1) the corresponding [ ] presented in the TR, or (2) of any model updates in response to Parts a. through e. of this request for additional information. [ ]

]

### RAI 3

The TR does not provide a discussion of how the updated rod-to-rod gap closure correlation is applied in downstream safety analysis methods -- it is only mentioned that "the rod-to-rod gap closure predicted as a function of fuel assembly exposure is used as an input to thermal limit evaluations (i.e., MCPR) for AREVA BWR fuel designs." Describe how the rod bow empirical model is used in downstream safety analyses. Consider the following NRC staff observations for additional context:

The discussion at the end of "Accepted Version of Exxon Nuclear Licensing Topical Report, XN-NF-85-67(P)(A), 'Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel' (Agencywide Documents Access and Management System (ADAMS) Accession No. ML081760201), Section 3.4.9, "Fuel Rod Spacing and Rod Bow" states:

[

]

Does this mean that spacings have never been reduced enough to warrant a minimum critical power ratio (MCPR) penalty? Is this still true? If so, what is the latest licensing basis that states this?

Further, TR ANP-2637, Revision 6, "BWR Licensing Methodology Compendium" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15282A224), Section 2.2.6, 'Rod Bowing,' states:

Rather than placing design limits on the amount of bowing that is permitted, the effects of bowing are included in the cladding overheating analysis by limiting fuel rod powers when bowing exceeds a predetermined amount. AREVA uses an approved methodology (Reference 2-9) to determine a rod-to-rod clearance closure limit below which a penalty is addressed on the MCPR and above which no reduction in MCPR is necessary. The methodology is based on empirical data (Reference 2-2) to calculate minimum end of life rod-to-rod spacing. The potential effect of this rod bow on thermal margin is negligible. Rod bow at extended burnup does not affect thermal margins due to the lower powers achieved at high exposure.

What approved TR describes how "the effects of bowing are included in the cladding overheating analysis by limiting fuel rod powers when bowing exceeds a predetermined amount"?

Reference 2-9 mentioned in the quoted passage above is XN-NF-82-06(P)(A), Supplement 1, Revision 2, "Qualification of Exxon Nuclear Fuel for Extended Burnup," Supplement 1, "Extended Burnup Qualification of ENC 9x9 BWR Fuel," Advanced Nuclear Fuels Corporation, May 1988. This reference does not give a formulation for the MCPR penalty that would be applied if rod-to-rod closure is greater than the 95 percent UTL given by the corresponding correlation. What approved topical report describes the MCPR penalty formulation?

#### **RAI 4**

- a. Describe the process for fuel assembly selection when fuel rod growth measurement data is generated for the measurement database supporting the corresponding correlation to ensure that the correlation remains unbiased (i.e., inconsistent data generation could invalidate the derived [ ]). Is growth measurement data entered into the database for all fuel rods in a given fuel assembly selected for fuel rod growth measurement?
- b. Similarly, describe the process for fuel assembly selection when internal water channel growth measurement data is generated for the measurement database supporting the corresponding correlation.

#### **RAI 5**

Is there any [ ] clad fuel rod growth data included in Figure B-1 of the TR? Including [ ] clad fuel rod growth data would be inappropriate since EMF-85-74(P)(A), Supplement 2, Revision 0, noted that fuels with [ ] and inclusion of this data could bias the data non-conservatively.

#### **RAI 6**

Regarding the fuel rod growth enhancement factor that accounts for the presence of chromia-doped fuel, the following statement is made: "[

]." It is understood that the mechanism for increased axial growth is the same; however, it is not clear that the *magnitude* of the effect will be the same. Provide data similar to that in Figure B-2 for SRA cladding to support the claim that the enhancement factor will be the same for fuel with either RXA or SRA cladding.

#### **RAI 7**

The summary regarding the BWR fuel rod growth correlation in Appendix B of the TR, states: "Based on the data and similarity in manufacturing processes, the BWR rod growth correlation is fully applicable to AREVA BWR fuel rod designs with SRA [Zircaloy-2] Zry-2 cladding."

- a. Has a similar correlation been developed and implemented for RXA cladding? If so, where is this discussed?
- b. Confirm that the RODEX4 rod growth model is unaffected by the updated fuel rod growth database in the TR. For example, determination of the rod free volume depends on the rod growth model. This rod growth model, described in Section 4.2.6, "Rod Axial Elongation" of TR BAW-10247PA, Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," doesn't currently include the effects of chromia-doped fuel which exhibits more rod growth compared to non-doped fuel. Also, describe any other equation constants and tuning parameters derived in the base topical report that are potentially affected by the new data provided in the TR. If AREVA believes that impacts to RODEX4 are beyond the scope of the TR review, explain where these issues have been addressed or will be addressed (e.g., in other supplements that have been previously approved or are currently under review).

#### **RAI 8**

It appears that some ATRIUM-10 data from the previously approved fuel assembly growth model in EMF-85-74(P)(A), Supplement 2, Revision 0, has been removed when comparing Figure C-1 of the TR and the figure in Reference A.2 of EMF-85-74(P)(A), Supplement 2, Revision 0. In particular, the 2 points around [ ] with values of approximately [ ] are no longer present in Figure C-1. Provide justification for why data points were removed from either the fuel assembly or fuel rod growth model development process if this is the case.

#### **RAI 9**

Why isn't an upper bound maximum fuel channel growth curve included in the TR as was done for the previously approved evaluation of fuel channel overlay with the lower tie plate seal spring in EMF-85-74(P)(A), Supplement 2, Revision 0? A value of [ ] was determined at a burnup of [ ] previously and it appears that the new data presented in Figure C-1 would cause a significant increase in the upper bound curve.

#### **RAI 10**

The update process for the models described in the TR is described in Section 5.0, "UPDATE PROCESS."

- a. Although the TR data appears to be predictable based on burnup alone, growth of SRA Zry-2 depends on factors such as the amount of cold work (i.e., manufacturing process)

and the presence of hydrogen or hydrides due to corrosion. Explain why the TR correlation will be adequate to bound future fuel rod designs that may have different manufacturing processes, plant water chemistry, etc.

- b. During the acceptance review, AREVA stated that fuel rod growth is independent of fuel design and that cladding material drives the need for different growth correlations. However, the need for an [ ], demonstrate otherwise. Given the provided data, explain why fuel rod growth will remain independent of future fuel designs (e.g., ATRIUM 11 and other evolutions of this design that may or may not contain fuel additives). This may be covered under Section 5.0, "Update Process," of the TR.
- c. Although the section states that models will be reviewed against a growing post irradiation examination database, it does not specify with what frequency. If the frequency is too low, data may be added that could non-conservatively invalidate current models without having to submit updated models for NRC review and approval. Specify an appropriate minimum frequency.
- d. The following statement does not contain a sufficient level of specificity: "The threshold for submittal of the growth and bow correlations is an increase of the correlation tolerance limits by one standard deviation." To fully understand the criterion, provide additional specificity. For example: (1) Provide the mathematical definition of the standard deviation being referred to and why it is appropriate (e.g., Why not use standard error?), and (2) Does the increase have to be observed over the entire burnup range, some subset of the burnup range, or something else?