AREVA

ANP-10334Q1NP
Revision 0

Response to Request for Additional Information - ANP-10334P

Q12™ Structural Material Topical Report

November 2016

AREVA Inc.

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

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Nomenclature

Acronym	Definition
AREVA	AREVA Inc.
FA	Fuel Assembly
LDL	Lower Design Limit
NRC	Nuclear Regulatory Commission
TR	Topical Report
UDL	Upper Design Limit

RAI-1

In section 12.0 of the topical report (TR), AREVA INC (AREVA) describes an update process which will be used to update the models discussed in sections 6.0 to 9.0 based on additional PIE data. For those models which AREVA intends to update, provide the following:

a. The specific model which will be updated.

b. A detailed description of how the model will be updated. (e.g., will the model form change? Will the coefficients change? Will only a subset of the coefficients change?) This should include a description of how each model was initially developed. For example, if a model was initially developed as polynomial fit to a set of data, and if more data will be obtained and a similar fit will be used, the initial model development needs to be described.

c. The limitation on the model change should be described. This should include details on which changes would necessitate further review by the U.S. Nuclear Regulatory Commission (NRC).

RAI-1 Response

a. Of the models described in ANP-10334P, in sections 6.0 to 9.0, the primary models which may be updated will be the oxidation and hydrogen pickup models (section 8.0). The other models described in ANP-10334P will not be updated. This is clarified in a red-line version of Section 12.0 which will replace the current section 12.0 when the approved version of the TR is issued.

b. Oxidation model:

The oxidation model form identified in section 8.2 of ANP-10334P is [

] used for components manufactured from other zirconium alloys and has been found to well represent zirconium alloy corrosion. The coefficients used in the model were established using Q12™ clad fuel rod oxide measurements. [

]

The best estimate guide tube oxide model was developed by application of a [ ] to the oxidation model developed from fuel rod oxide measurements. [

]

[

]

Hydrogen model:

The hydrogen model form identified in section 8.4 of ANP-10334P is well established for components manufactured from other zirconium alloys and well represents the hydrogen content of zirconium alloys following corrosion. [

]

[

]

c. When [ ] the results will be compared against predicted values using the models [

]

[

]

RAI-2

In section 12.1 and 12.2 of the TR, AREVA describes an update process which will be used to update the Fuel Assembly and Spacer Grid Growth Models. AREVA should provide the following details about the methods:

a. What criteria is used to determine when the generic upper design limit (UDL) and lower design limits (LDL) will be applied to a new assembly design?

b. What criteria is used to determine if a design specific UDL and LDL may be initially applied and/or updated?

c. How does the number of data points in the various regions of burn-up impact the design specific UDL and LDL?

d. How is design specific UDL and LDL mathematically defined?

e. Under what conditions would the design specific UDL and LDL not be used? (e.g., if design specific was not bounded by the generic, which one would be used?)

f. What criteria is used to update the design specific UDL and LDL?

g. What conditions would necessitate a submittal to the NRC? (e.g., what if the generic model were determined to be non-conservative for a fuel design?)

RAI-2 Response

a. The criterion used to determine when the generic fuel assembly (FA) growth upper and lower design limits shown in [ ] of ANP-10334P Revision 0 are applied is as follows: [

] This is clarified in a red-line version of Section 12.0 which will replace the current section 12.0 when the approved version of the TR is issued.

The generic spacer grid growth upper design limit shown in [ ] of ANP-10334P Revision 0 will be [

] This is clarified in a red-line version of Section 12.0 which will replace the current section 12.0 when the approved version of the TR is issued.

b. A design specific fuel assembly growth UDL and LDL may be applied [

]

[

]

c. The number of data points in the burnup range of application affects [

]

d. The [

] are defined by the Owen's 95/95 one-sided upper and lower tolerance limits (Refs. 2-1 and 2-2). The mathematical relationship is:

UTL: $y_{pred}(x_o) + k * s_{reg}$

LTL: $y_{pred}(x_o) - k * s_{reg}$

where $y_{pred}(x_o)$ is the expected value of the regression at x_o. The term s_{reg} is the standard error of the regression model, and k is the Owen's factor, which is dependent upon the number of degrees of freedom as established by the number of data points, the desired confidence level, and the proportion of the population covered. The regression model may be expressed as a linear or polynomial function of burnup.

A standard hypothesis test, i.e., the t-test, is used for ensuring the quality of multiple linear regression models. The test determines the significance of a given predictor coefficient in the presence of the other predictor coefficients in the model.

For the t-test, given the null hypothesis that the predictor coefficient is not significant, the calculated t-value for a given predictor coefficient must satisfy the expression below for the null hypothesis to be rejected and for the predictor coefficient to be considered significant.

$t > t_{.025}$ or $t < -t_{.025}$

where $t_{.025}$ is the critical student t value at the 5% level of significance for a two sided distribution.

If for a given set of [ ] the regression model coefficients cannot be shown to be significant, then the [ ] will continue to be used.

A test is also made to confirm that the regression model errors have a normal distribution. The Anderson-Darling test is used to compare the empirical cumulative distribution function of a data set with the distribution expected if the data were normal (Reference 2-3). If this observed difference is sufficiently large, the test will reject the null hypothesis of population normality. The Anderson-Darling test determines the p-value for determining the validity of the null hypothesis that the errors have a normal distribution. Thus, to accept the regression model errors as a normal distribution, the calculated p-value must be greater than or equal to .05.

If the regression model errors for the [ ] cannot be shown to have a normal distribution, then the [ ] will continue to be used.

The coefficient of determination, R^2, is also calculated, which provides a measure of the proportion of the total variation that is explained by the regression model. The maximum possible R^2 value is 1.0, and the desired R^2 is the highest value of the regression models evaluated in concert with satisfying the criteria for the t-test and normality test.

[

]

Table 2-1 provides a summary of the regression model tests for the [

] where linear, quadratic, and cubic polynomial regression models are evaluated. The results [

]

e. If the [

]

f. The [

] with the approach defined in the response to RAI-2d.

g. If any data [

]

References for RAI-2 Response:

1 SCR-607, "Factors for One-Sided Tolerance Limits and for Variables Sampling Plans", D.B. Owen, Sandia Corporation Monograph, March 1963.

2 Introduction to Probability and Statistics, 10th Edition, W. Mendenhall, R. Beaver, B. Beaver, Duxbury Press, 1999.

3 Anderson, T.W. and Darling D.A., "A Test of Goodness of Fit" Journal of American Statistical Association, Vol. 49, No. 268, (December 1954), pp. 765-769.

Table 2-1
[ ] Fuel Assembly Growth Example - Regression Fit Statistical Tests and Normality Test Comparison

[

]

Figure 2-1
[ ] Fuel Assembly Growth UDL and LDL Example

[ ]

RAI-3

The TR requests permission for AREVA to deliver batch quantities of assemblies using Q12 structural materials without the prior delivery and post-irradiation examination of lead test assemblies for that particular fuel design. Given the lack of in-reactor experience, a surveillance program is prudent on the lead batch for each application. Please describe the surveillance program (e.g., data collection, model validation, reporting) by which AREVA will ensure that these assemblies continue to behave as described in the topical report.

RAI-3 Response

The response to RAI-3 will be provided at a later date.

RAI-4

At the June 14-15, 2016 audit, AREVA indicated that additional post-irradiation examinations had been completed since the submission of the topical report. Please provide additional data collected to date on irradiated fuel assemblies.

RAI-4 Response

Fuel assembly [

] These measurements are shown in Figure 4-1 with the previous database of FA growth measurements and UDL/LDL growth curves provided in section 10.0.

Figure 4-1

Updated [ ] Database

[ ]

RAI-5

In section 8.2 of the TR, AREVA describes the guide tube oxidation model. NRC staff request that AREVA provide further details regarding guide tube oxidation:

a. What plans does AREVA have for increasing the number of data points that can be used to correlate the guide tube oxidation rate to the fuel rod model?

b. What design calculations does oxide thickness affect directly and indirectly?

RAI-5 Response

a. Current plans [

]

b. Calculations for [

]

ADDITIONAL ITEMS

1. During a phone call held with NRC on October 19th, 2016, the NRC verbally requested that AREVA provide a comparison of FA growth for CE designs compared to Westinghouse 17x17 designs, utilizing a common structural guide tube material. The information presented below in Figure 6-1 shows that for fuel assemblies using [ ] guide tubes, the growth trend of CE fuel assemblies is similar and slightly lower than that for a W17 fuel assembly design. This provides supporting justification for application of a generic UDL/LDL to all PWR assembly designs in the absence of design specific data.

Figure 6-1

[ ] Comparison

2. During a review of the grid growth model shown in Figure 10-2 of ANP-10334P, it was determined that there was a slight error in two of the grid growth data points. A markup of Figure 10-2 with the corrected data is included in the markup pages submitted as part of this RAI Response.

ANP-10334NP – Q12™ Structural Material Topical Report Markups

Figure 10-2 Upper Design Limit for Q12™ Grid Growth Using M5® and Q12™ Grid Growth Data

[

]

12.0 UPDATE PROCESS

AREVA plans to continue to monitor the performance of Q12™ in lead assemblies and batch fuel, both in the U.S. and in Europe. Through various material test programs AREVA also plans to continue to gather in-core, out-of-core, and test reactor data on Q12™. As data are obtained for more burnups and for an increasing number of fuel designs, the models presented in this report may require adjustment. These activities allow AREVA to continuously expand its knowledge and improve its predictive performance tools for Q12™.

As Q12™ data are obtained the AREVA PIE database will be expanded. Periodically, the models discussed in Section 8.0 will be reviewed against the growing database. If the data support a modification to any of the Q12™ models used for design analyses, the internal AREVA design change process will be followed. This change process includes documentation and justification of the change and evaluation of the impact on future design analyses. Any changes to the models presented in Section 8.0 will be maintained in an internal AREVA document. Changes to the models in Section 10.0 are discussed in Sections 12.1 and 12.2.

12.1 *Fuel Assembly Growth Model*

Because of the importance of fuel assembly growth, it is appropriate to impose additional criteria for changing the design limits for growth. The [ ] UDL for the growth of FAs with Q12™ guide tubes, presented in Section 10.1, provides a significant margin to the current database of FA growth measurements. [

]

The following criteria will be used to determine when the UDL and LDL can be modified. AREVA's experience shows [

] may be defined through this update process for any design [

] Any design-*specific* limits established through this update process will be required to adhere to the *update process described in the response to RAI 2*.

12.2 *Spacer Grid Growth Model*

The space grid growth model shown in Figure 10-2 will remain applicable to all Q12™ grid designs. AREVA will submit any future changes to the current space grid upper tolerance limit for review and approval by the NRC.

12.3 *NRC Notification*

A summary of any updates made to the models will be provided to the NRC in a letter report for information.

The update process ensures that design margins are maintained, and it examines the updates with regard to the limitations specified in the NRC's Safety Evaluation Report. If the updates are outside of the NRC's Safety Evaluation Report limitations, then one of the following actions will be taken:

1. No credit taken for the update
2. Update documented for NRC review and approval
3. Update included in a License Amendment Request for site-specific approval