AREVA

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U.S. Nuclear Regulatory Commission
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Rockville, MD 20852

Response to U.S. EPR Design Certification Application RAI 571, Supplement 1

Ref. 1: E-mail, Amy Snyder (NRC) to AREVA NP Inc. (AREVA NP), "U.S. EPR Design Certification Application FINAL RAI No. 571, FSAR Ch. 4," February 8, 2013.

Ref. 2: E-mail, Dennis Williford (AREVA NP Inc.) to Amy Snyder (NRC), "Response to U.S. EPR Design Certification Application FINAL RAI No. 571, FSAR Ch. 4," March 11, 2013.

Ref. 3: E-mail, Dennis Williford (AREVA NP Inc.) to Amy Snyder (NRC), "Updated Fuel Seismic Closure Plan – Revised Dates for Submittals," May 2, 2013.

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. AREVA NP Inc. (AREVA NP) provided a schedule for the response to RAI 571 on March 11, 2013 (Reference 2). AREVA NP provided a revised schedule for the final response to RAI 571 on May 2, 2013 (Reference 3).

The enclosure to this letter provides a complete response to the single question in RAI 571. AREVA NP considers some of the material contained in the enclosed response to be proprietary. As required by 10 CFR 2.390(b) an affidavit is enclosed to support the withholding of the information from public disclosure. A proprietary and a non-proprietary version of this response are enclosed.

The following table indicates the respective pages that contain AREVA NP's final response to the subject question.

Question #	Start Page	End Page
RAI 571 – 04.02-18	2	19

This concludes the formal AREVA NP response to RAI 571, and there are no questions from this RAI for which AREVA NP has not provided a response.

D077
NRO

AREVA NP INC.

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Tel.: 434 832-3000 - www.areva.com

If you have any questions related to this information, please contact Len Gucwa by telephone at 434-832-3466, or by e-mail at Len.Gucwa.ext@areva.com.

Sincerely,

Pedro Salas, Director
Regulatory Affairs
AREVA NP Inc.

Enclosures:

1. Proprietary Version of "Response to Request for Additional Information No. 571, Supplement 1"
2. Non-Proprietary Version of "Response to Request for Additional Information No. 571, Supplement 1"
3. Notarized Affidavit

cc: A. M. Snyder
Docket 52-020

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. (AREVA NP) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the document titled "Response to U.S. EPR Design Certification Application RAI 571, Supplement 1," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information":

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(c) and 6(d) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 16th

day of May 2013.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/2014
Reg.#7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2014

Response to

Request for Additional Information No. 571, Supplement 1

2/8/2013
U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 04.02 - Fuel System Design
Application Section: 04.02
SRSB Branch

Question 04.02-18:

Fuel bundle hydraulic loss or pressure drop under rated flow conditions is an important fundamental design parameter to the core thermal hydraulic analysis, fuel assembly hydraulic lift evaluation, and in-vessel component lift force evaluation. This parameter is usually unique to each fuel design as it is affected by the spacer grid design and fuel pin and guide tube dimension and layout. Accurate measurements of the pressure drop, and data processing, are necessary to define the total form loss coefficient of the fuel bundle.

For the current fuel assembly design documented in the FSAR, AREVA performed hydraulic testing in 2005. The fuel bundle form loss coefficient developed from this set of testing was used by all the relevant design analyses and evaluations. During a December 11-14, 2012 audit, AREVA made a document available for staff review, which discussed the impact of the effect of spacer grid surface roughness changes and showed the potential for a reduction in core pressure drop. The analysis estimated that using polished spacer grids would affect the original 2005 testing results. Based on the discussions at the audit, and the documentation review by the staff, it is not clear what set of loss coefficients are used for the pressure drop credited in the FSAR.

1. What testing was conducted to develop the fuel bundle loss coefficient used for the current FSAR analyses?
2. What is the plan for developing a new loss coefficient for the new bundle design? Will other relevant testing be used to develop the new loss coefficient? If so, discuss the testing and the relevance to the new bundle design.
3. How will the new loss coefficient affect the current FSAR analysis?

Response to Question 04.02-18:

Question 04.02-18-Part 1:

1. What testing was conducted to develop the fuel bundle loss coefficient used for the current FSAR analyses?

Response to Question 04-02-18-Part 1:

This response identifies the test program, test facilities, and tests that were used to develop the fuel assembly loss coefficient used for the current U.S. EPR FSAR Tier 2 analyses. Since the testing occurred in the past over a period of more than a year, a timeline is provided in Figure 04.02-18 – 1 to show:

- When a specific pressure drop test (or series of tests) was performed.
- What fuel assembly component loss coefficient was based upon the test(s).
- When the subsequent test reports were issued.
- When the loss coefficient was established for application in the current U.S. EPR FSAR Tier 2 safety analyses.

The U.S. EPR HTP fuel assembly is represented by individual component loss coefficients. The component loss coefficients, used for the U.S. EPR FSAR Tier 2 analyses, were obtained from several hydraulic tests performed in the 2004-2005 timeframe for AREVA's HTP LX fuel assembly pressure drop test program. These tests collectively formed the test basis for the fuel assembly loss coefficients. The HTP-LX test program has served multiple functions for AREVA with its series of pressure drop tests for fuel design development and component pressure drop characterization. The test program provided the following:

- Measured pressure drops for the EPR fuel design components used for the Olkiluoto 3 (OL3) EPR and U.S. EPR applications.
- Measured pressure drops for fuel assembly hardware that could be implemented in existing operating plants using the HTP fuel design.
- Measured pressure drop sensitivities for HTP and HMP spacer grid modifications (e.g., strip thickness, weld nugget size, strip deburring, and tumbling).

The HTP-LX pressure drop test program utilized two pressure drop test facilities to accomplish its testing objectives: the Hermes-P test loop at Cadarache, France and the Magaly loop at LeCreusot, France. The Hermes-P loop is owned and operated by the French Alternative Energies and Atomic Energy Commission (CEA) and supports full-scale prototype testing at reactor operating temperatures and pressures. The Magaly loop is owned and operated by AREVA's Technical Center and supports part-length fuel bundle testing at temperatures and pressures that produce fluid conditions at Reynolds Numbers up to ~300,000 where hydraulic resistance extrapolation to reactor operating conditions is used to 500,000. Test data from each of these two test loops were used during the course of establishing the U.S. EPR HTP fuel assembly loss coefficient basis supporting the current U.S. EPR FSAR Tier 2 analyses.

Section 3.0 of the topical report ANP-10285P (Reference 1) describes the general U.S. EPR fuel assembly design and the specific hardware components as evaluated for the U.S. EPR

FSAR Tier 2 analyses. Table 04.02-18 – 1 provides a list of general U.S. EPR fuel assembly design characteristics and those of the prototype assemblies used in the tests for each test loop. Note that different prototype fuel assemblies were built and tested in Magaly in order to measure the specific hardware components used for the U.S. EPR fuel assembly design. The part length prototype assemblies for the Magaly tests are typically tailored for the collection of data for one component.

The 2004 Hermes-P pressure drop test for the HTP-LX program used a prototype fuel assembly that had a full complement of hardware components (i.e., a full-length assembly with a FUELGUARD™ bottom nozzle and a top nozzle, HTP intermediate spacer grids, lower and upper HMP end spacer grids, 264 fuel rods, 24 guide tubes, and a central instrument tube). The U.S. EPR fuel assembly design is different from the typical AREVA HTP fuel design in that it has a 265th fuel rod in lieu of the central instrument tube. The impact of this test prototype difference was determined to be worth [ ] in the fuel assembly loss coefficient when applying the prototype pressure drop results to the U.S. EPR fuel design. However, no credit in reduced pressure drop and lower loss coefficient has been taken in the U.S. EPR fuel assembly component loss coefficients for this small effect.

The use of a slightly higher pressure drop is conservative in the determination of core pressure drop, hydraulic lift pressure drop, maximum core bypass flow fractions (used for DNB analyses), and net fuel assembly hold down forces. The impact of a [ ] higher pressure drop is deemed negligible for the DNB, Non-LOCA, and LOCA analyses.

As shown in Table 04.02-18 – 1, the Hermes-P pressure drop test for the HTP-LX program provided the measured pressure drop basis for the bottom nozzle (FUELGUARD™) and the HTP spacer grid and their corresponding loss coefficients for the U.S. EPR fuel assembly design supporting the U.S. EPR FSAR Tier 2.

The Magaly prototype test assemblies, as noted earlier, are part-length test assemblies. The assemblies contain full-scale components when determining the specific component pressure drop by using shorter simulated fuel rods, guide tubes and instrument tubes to produce sufficient size axial spans to obtain accurate pressure drop measurements across the component.

Several individual pressure drop tests were performed in the Magaly loop to characterize the pressure drop impact of various grid strip changes and manufacturing changes that could be considered for the HTP and HMP spacer grid designs. These tests examined changes in strip thickness, strip intersection weld nugget size, and manufacturing changes (deburring and tumbling). One of these tested HMP designs (in strip thickness and weld nugget size) became the specific HMP design for the U.S. EPR fuel design. The corresponding loss coefficient for this specific HMP grid design was used in supporting the U.S. EPR FSAR Tier 2.

Although AREVA had the Magaly test data for the HTP grid pressure drop benefits of deburring and tumbling in 2006, a decision was made in 2006 to not adopt these benefits for the HTP grid for the U.S. EPR fuel design. This decision provided an opportunity to not use these expensive manufacturing techniques for the first reload of U.S. EPR fuel. It was deemed easier to implement these expensive manufacturing techniques at some later time, should they be desired, than to incorporate them into the HTP design and then remove them, should that be desired. In addition, the lower and upper HMP grid loss coefficients were comparably increased. This conclusion was, again, resting on the general conservative nature of using a higher loss coefficient for many of the analyses relying on grid loss coefficients.

Additional Magaly pressure drop tests were performed to determine the impact of the inclusion of a quick-disconnect (QD) feature and the pressure drop benefit of rounding the inlet region of the top nozzle tie plate which was included on the U.S. EPR fuel design. The Magaly tests were needed because the 2004 Hermes-P test configuration did not utilize a quick-disconnect feature nor did its top nozzle have a rounded inlet region. These Magaly pressure drop tests demonstrated that the slight pressure drop increase attributed to the small flow area reduction due to the quick-disconnect connection to the tie plate was offset by the pressure drop decrease attributed to the rounding of the inlet region of the tie plate. This test formed the design basis for the top nozzle loss coefficient used to support the U.S. EPR FSAR Tier 2.

These select pressure drop tests in the Hermes-P and Magaly test loops provided measured pressure drop data that was used to collectively define the form loss coefficients for the HTP and HMP spacer grids and the top and bottom nozzles for the U.S. EPR fuel assembly design supporting the U.S. EPR FSAR Tier 2. The loss coefficient values at a Reynolds Number of 500,000 are shown in Table 04.02-18 – 2. The corresponding core pressure drop at 100% full power for the U.S. EPR fuel assembly design supporting the U.S. EPR FSAR Tier 2 analyses, based on the 2006 component loss coefficient basis, is provided in Table 04.02-18 – 3.

Question 04.02-18-Part 2:

2. What is the plan for developing a new loss coefficient for the new bundle design? Will other relevant testing be used to develop the new loss coefficient? If so, discuss the testing and the relevance to the new bundle design.

Response to Question 04-02-18-Part 2:

AREVA's approach to develop the new loss coefficients for the spacer grids is provided below. Other relevant pressure drop testing was used to define the individual component loss coefficients for the HTP grids, bottom nozzle, and modified HTP grids.

Figure 04.02-18 – 2 provides a timeline of the pressure drop testing activities and the loss coefficient calculations for the AREVA approach to develop the new loss coefficients for the U.S. EPR fuel assembly design reflecting the modifications to increase spacer grid strength. This timeline is similar in format to Figure 04.02-18 – 1 for illustrating the activities of testing, issuance of test reports, and establishment of the component loss coefficients. Table 04.02-18 – 4 provides characteristics of the prototype test assemblies relative to the revised U.S. EPR fuel design.

The revised U.S. EPR fuel design reflects modifications to improve the mechanical strength of the spacer grids. The specific modifications associated with the HTP grid are:

- Thickening of the interior grid strips of the two centrally positioned (axially) HTP grids by [ ] to produce [ ] thick interior grid strips with the [ ] weld nuggets.
- Increase in the weld nugget size of the remaining six HTP grids by [ ] to produce [ ] weld nuggets. The weld nugget size term used here is the distance across the width of the nugget 45° from the planes of the intersecting strips.

HTP grid modifications of this type and magnitude would tend to increase the hydraulic resistance of the spacer grid design. Therefore, in order to minimize the hydraulic resistance impact of the HTP grid modifications on the U.S. EPR FSAR Tier 2 analyses, AREVA made the following changes:

1. Use HTP grid strip manufacturing techniques that reduce the component loss coefficient to offset the pressure drop increase for the HTP grid modifications as discussed above.
2. Use the more recent Hermes-P pressure drop test data, obtained in the 2007 timeframe, where the benefits of deburring and tumbling (during the strip manufacture) are measured for the HTP spacer grids.

   AREVA performed an additional pressure drop test in the Hermes-P, labeled AGORA 7HL in Figure 04.02-18 – 2, on a full length prototype fuel assembly containing 4 HTP grids that were deburred and tumbled during strip manufacture and 4 HTP grids that were only deburred during strip manufacture. The prototype used a FUELGUARD™ bottom nozzle, HMP lower end grid, and an AFA 3GL top nozzle with quick disconnects. Like the 2004 Hermes-P test HTP-LX prototype, the 2007 AGORA 7HL prototype contained 264 rods, 24 guide tubes, and a central instrument tube.

3. Determine whether one or both manufacturing processes for the HTP grids are necessary to obtain the desired hydraulic resistance reduction.

   The evaluation of the pressure drops from the two sets of 4 HTP grids revealed that the pressure reduction benefit is predominately obtained from the deburring process. Therefore, the HTP loss coefficient for deburring only was adopted for the U.S. EPR fuel assembly design to avoid the unnecessary cost attributed to the additional manufacturing process of tumbling.

4. Determine the component loss coefficients for the U.S. EPR fuel design (prior to modification) to increase the spacer grid strength using the 2007 Hermes-P pressure drop test data and earlier pressure drop test data, as appropriate. These loss coefficient calculations were performed in 2013.

   HTP grid: The HTP loss coefficient was based on the 2007 Hermes-P test where a set of four HTP grids utilized grid strips that were deburred.

   HMP grid The HMP loss coefficient continued to be based on specific 2005 Magaly testing (in strip thickness and weld nugget size) for the U.S. EPR design.

   Bottom Nozzle: The FUELGUARD™ bottom nozzle loss coefficient was conservatively based on the 2007 Hermes-P test when the loss coefficient was found to be slightly higher than when measured in the 2004 Hermes-P test.

   Top Nozzle: The top nozzle loss coefficient continued to be based on the 2005 Magaly pressure drop test that confirmed the slight pressure drop increase attributed to the small flow area reduction due to the quick-disconnect connection to the tie plate was offset by the pressure drop decrease attributed to the rounding of the inlet region of the tie plate.

5. Apply the results of the Magaly HTP pressure drop tests performed from February 2005 through 2007, where the pressure drop sensitivity of weld nugget size and strip thickness were measured, respectively. Apply the resulting loss coefficient sensitivities to the HTP grid to reflect the impact of the HTP grid modifications for seismic reasons to complete the component loss coefficients comprising the revised U.S. EPR fuel design. These loss coefficient calculations were performed in 2013.

   The Magaly HTP pressure drop tests, starting in February 2005, examined the pressure drop sensitivity to the interior strip thickness. These tests formed the basis of a numerical adjustment for the loss coefficient change for the specific strip thickness increase of [ ] for the two centrally positioned (axially) HTP grids.

   The Magaly HTP pressure drop tests, starting in February 2005 and concluding in May 2005, examined the pressure drop sensitivity to the size of weld nuggets. These tests formed the basis of a numeric expression for the loss coefficient change for specific weld nugget size increase of [ ] for the remaining six HTP grids.

The approach to develop new loss coefficients, shown above, led to the establishment of component loss coefficients shown in Table 04.02-18 – 5 for the revised U.S. EPR fuel assembly design. The corresponding core pressure drop for the U.S. EPR fuel assembly design supporting the U.S. EPR FSAR Tier 2 analyses, based on the 2013 component loss coefficient basis, is provided in Table 04.02-18 – 6. The new loss coefficients produce a 100% power core pressure drop [ ] psi lower than the core pressure drop previously predicted when using the 2006 loss coefficient basis in Table 04.02-18 – 2.

During the preparation of this RAI response, analyses and supporting references regarding pressure drop testing and loss coefficient determination were re-examined to confirm the specific relevance of tested components to those of the U.S. EPR fuel assembly design. This re-examination identified several issues that have been captured in the AREVA Corrective Action (CR) program. These issues were ultimately found to have an insignificant impact on the 2013 component loss coefficients shown in Table 04.02-18 – 5. One of the issues was resolved by using additional Magaly pressure drop tests, from 2010, that allowed the determination of the loss coefficient impact associated with HMP grid sleeves. Grid sleeves are small devices used for attaching the HMP grids to the guide tubes. These Magaly tests have been included in the timeline in Figure 04.02-18 – 2 to reflect their relevance in supporting the adequacy of the 2013 revised loss coefficient basis.

Question 04.02-18-Part 3:

3. How will the new loss coefficient affect the current FSAR analysis?

Response to Question 04.0-2-18-Part 3:

The revised loss coefficient for the revised U.S. EPR fuel assembly design was found to be overall lower than the loss coefficient for the U.S. EPR fuel design used in support of the U.S. EPR FSAR Tier 2. This reduction in loss coefficient was found to reduce the overall core pressure drop by **[ ]** psi, based on results in Table 04.02-18 – 6 and Table 04.02-18 – 3, relative to the pressure drop predicted for the U.S. EPR FSAR Tier 2 analyses. The axial distribution of the fuel design hydraulic resistance changed with the revised fuel assembly design because of the slightly different HTP grid sets; the two centrally located HTP grids with thicker interior strips and the remaining six grids with larger weld nuggets. All of these changes have been incorporated into the assessment of the impact of the revised U.S. EPR fuel assembly design change on the U.S. EPR FSAR Tier 2.

As noted in Part 2 of this response, several small errors were identified in the component loss coefficient determinations and recorded in the AREVA Corrective Action Program. The errors were evaluated and found to impact the overall core hydraulic resistance by a negligible 0.05%. Consequently, the results reported in Parts 2 and 3 of this response will not be revised to reflect the correction of these small errors.

Core Bypass Flow Rate

The core bypass flow rate calculations were revised to incorporate the revised U.S. EPR fuel assembly design component loss coefficients. The nominal best-estimate core bypass percentage and the total unrecoverable reactor vessel pressure drop values are reported in the U.S. EPR FSAR Tier 2. These values have changed by a small amount and will be updated in the U.S. EPR FSAR Tier 2. The maximum allowable core bypass percentage, and the corresponding percentage of RCS flow which passes through the core, are also reported in the U.S. EPR FSAR Tier 2. The use of the revised loss coefficients shows that the maximum core bypass is less than the maximum allowable core bypass value reported in the U.S. EPR FSAR Tier 2, therefore the U.S. EPR FSAR Tier 2 will not be revised to reflect this change.

LOCA

The impact of the revised component loss coefficients was determined via sensitivity studies for the Small Break Loss of Coolant Accident (SBLOCA) and Realistic Large Break Loss of Coolant Accident (RLBLOCA) analyses. The changes in PCT for the limiting cases were within ±15°F. These results demonstrate that the original U.S. EPR FSAR Tier 2 analyses adequately represent the U.S. EPR design. The U.S. EPR FSAR Tier 2 does not require revision to reflect this negligible impact.

Non-LOCA Safety Analyses

The non-LOCA safety analyses supporting the U.S. EPR FSAR Tier 2 are not impacted by the fuel assembly design changes. Two core flow related parameters are important to the performance of non-LOCA safety analyses: (1) core bypass flow rates and (2) total pressure drop across the core.

A comparison of the calculated core bypass flow rates used in the non-LOCA safety analyses supporting the U.S. EPR FSAR Tier 2 show that the maximum core bypass flow rates calculated as a result of the fuel grid design changes are bounded by those used in the performance of the U.S. EPR FSAR Tier 2, Chapter 15, safety analyses. Additionally, the changes to the nominal bypass flow rates are negligible to those used in the performance of the best-estimate U.S. EPR FSAR Tier 2, Chapter 7, Diversity and Defense-in-Depth analyses.

The core pressure drop at 100% full power using the 2013 loss coefficient basis is **[ ]** psi lower than the 2007 predicted core pressure drop using the 2006 loss coefficient basis. This change is considered to have a negligible impact on the non-LOCA safety analysis results.

Core DNBR

The U.S. EPR core is analyzed as a full core of the same fuel assembly design. Therefore, any small hydraulic resistance changes that occur at the same axial plane for all the fuel assemblies will have a minimal impact on the flow redistribution that would have occurred without the small hydraulic resistance changes. Minimum DNBR predictions were made for several transients (main steam line break, uncontrolled bank withdrawal from hot zero power, and a control rod ejection) to see the impact of the component loss coefficients for the revised U.S. EPR fuel assembly design. The minimum DNBR predictions for the transients were found to be bounded by the corresponding minimum DNBR predictions for the U.S. EPR FSAR Tier 2 analyses. This conclusion is also influenced by the prior use of a conservative core bypass flow rate for the DNBR predictions for the U.S. EPR FSAR Tier 2 analyses. Therefore, the DNBR predictions supporting the U.S. EPR FSAR Tier 2 remain applicable for the revised U.S. EPR fuel assembly design.

Pressure Drops for Hydraulic Lift Forces

The limiting fuel assembly pressure drops for the revised fuel assembly design were computed for determining the limiting hydraulic lift forces for the typical spectrum of operational states: fourth RC pump startup, hot full power at the upper temperature band limit, hot full power at the lower temperature band limit, hot zero power at the upper temperature band limit, hot zero power at the lower temperature band limit, 120% pump overspeed at the upper temperature band limit and full power, and 120% pump overspeed at the lower temperature band limit and full power. The component loss coefficients for the revised U.S. EPR fuel assembly design were found to produce limiting fuel assembly pressure drops smaller than those supporting the U.S. EPR FSAR Tier 2 analyses. The U.S. EPR FSAR Tier 2 will be updated to reflect the use of the reduced pressure drops for the subsequent fuel assembly hold down calculations.

Fuel Assembly Hold Down

The limiting fuel assembly pressure drops computed for the revised fuel assembly design have been applied to the spectrum of operational states noted above in the pressure drop calculations. The acceptability of the fuel assembly hold down system for the hydraulic lift forces determined for the operational states has been demonstrated using AREVA's NRC-approved statistical fuel assembly hold down methodology.

A number of issues relative to the use of the statistical hold down (SHD) methodology (Reference 2) have been identified in the AREVA Corrective Action (CR) program. The issues range from having generic applicability to U.S EPR specific applicability. A summary of the four

(4) issues is provided herein, along with a description of the revised results with respect to fuel assembly hold down margin. The results of the re-analysis are provided in Table 04.02-18 – 7. The following four issues have been identified and corrected or revised for the U.S. EPR fuel assembly hold down evaluation.

1) Source Code Error:

   Within the SHD code, an incorrect algorithm was identified which caused some of the variable uncertainties to be treated with a normal distribution instead of the intended and more conservative uniform distribution. The issue was generic to all SHD evaluations and resulted in a non-conservative outcome (i.e., resulted in a net increase in fuel assembly hold down margin).

2) Uncertainty Distribution Assignment Error:

   The uncertainties for three of the more significant variables (relative to their influence on fuel assembly hold down margin) were incorrectly assigned (via inputs to the code) as normally distributed instead of the more conservative and appropriate uniformly distributed. The three variables were fuel assembly growth, hold down spring relaxation, and hold down spring set. The issue was generic to all SHD evaluations and resulted in a non-conservative outcome (i.e., resulted in a net increase in fuel assembly hold down margin).

3) Source Reference Error:

   The values provided for the spring relaxation variable were inconsistent with the equations in the SHD code. The issue was specific to the U.S. EPR FSAR Tier 2 analysis and resulted in a non-conservative outcome (i.e., resulted in a net increase in fuel assembly hold down margin).

4) Overly Penalizing Treatment of Input Variables:

   This issue is related to a conservative practice within the methodology, where specific variables are treated as independent when they are in fact inter-dependent. This practice results in a conservative outcome for fuel assembly hold down margin and, as such, is not considered to be an error. The SHD process treated all contributing spring deflection variables as "independent". It has been recognized that several of the "independent" variables are "inter-dependent", specifically hold down spring mechanical set, hold down spring relaxation, and fuel assembly growth. As an example, fuel assembly growth due to irradiation causes the hold down spring to compress more over time and leads to more hold down spring mechanical set. Therefore, hold down spring mechanical set is clearly dependent on fuel assembly growth (i.e., high hold down spring mechanical set can only occur when there is high fuel assembly growth). Treatment of these "inter-dependent" variables as "independent" results in output values which cannot exist in reality due to the Monte Carlo propagation method within the SHD code. For example, the SHD code will independently assign random values for each variable. With the large number of propagations (10,000), there are multiple cases where the random value for hold down spring mechanical set is on the high side of its tolerance and the random value for fuel assembly growth is zero (consistent with the lower limit of the fuel assembly growth curve). Since high hold down spring mechanical set can only occur when there is high fuel assembly growth, the result is an unrealistic compounding of variables. This compounding effect leads to an exaggerated value of the standard deviation (i.e., an increase in the fuel assembly hold down margin uncertainty).

The issue was generic to all SHD evaluations and resulted in an overly conservative outcome (i.e., resulted in a net decrease in hold down margin). An alternate approach has been identified, where the most significant inter-dependent variables (i.e., hold down spring mechanical set, hold down spring relaxation, fuel assembly growth) are combined into a single term, which results in the recognition of their inter-dependence. This treatment is within the NRC approved SHD methodology, which recognizes that variables, uncertainties, and methods for determining variable values can change on a case by case basis in addition to variables and uncertainties being added or deleted (Reference 2, pages 2 and 17). The alternate application maintains the same; net fuel assembly hold down equations accounting for all axial forces; terms which make up the spring deflection variable; variable types included in the Monte Carlo propagation; methods used to define the variable uncertainties (i.e., normal or uniform); series of statepoints covering various plant conditions; statistical protection (95% level with 95% protection).

The U.S. EPR fuel assembly hold down analysis was revised per the NRC approved methodology (Reference 2) to correct the errors identified above and to change the treatment of the most significantly inter-dependent variables: hold down spring mechanical set, hold down spring relaxation, fuel assembly growth. The re-evaluation continues to result in positive hold down margins (Table 04.02-18 – 7) for all normal operating statepoints. The prior U.S. EPR FSAR Tier 2 conclusion remains valid for the corrected calculations that no fuel assembly liftoff will occur during normal operation except for the potential 120% pump overspeed condition.

References:

1. ANP-10285P, U.S. EPR Fuel Assembly Mechanical Design Topical Report, October 2007.
2. BAW-10243P-A, Statistical Fuel Assembly Hold Down Methodology, September 2005.

FSAR Impact:

U.S. EPR FSAR Tier 2, Chapter 4 will be revised as described in the response and markups will be provided in a separate transmittal.

Table 04.02-18 – 1: Characteristics for the U.S. EPR Fuel Assembly Design Supporting the U.S. EPR FSAR Tier 2 Analyses and the Prototype Fuel Assemblies Tested in the Hermes-P and Magaly Loops

Description	U.S. EPR Fuel Design	2004 Hermes-P Prototype Assembly	2005 Magaly Prototype Assembly [2]	2005 Magaly Prototype Assembly [2]
Grid Array	17x17	17x17	17x17	17x17
Intermediate Spacer Grid	HTP (no deburring and tumbling)	HTP [1] (no deburring and tumbling)	–	–
Lower and Upper End Spacer Grids	HMP	HMP	–	HMP [1]
Number of Fuel Rods	265	264	264	264
Fuel Rod Outer Diameter, in	0.374	0.374	0.374	0.374
Fuel Rod Pin Pitch, in	0.496	0.496	0.496	0.496
Number of Guide Tubes	24	24	24	24
Guide Tube Outer Diameter, in	0.490	0.490	0.490	0.490
Number of Instrument Tubes	0	1	1	1
Top Nozzle	AFA 3GL equipped with a Quick Disconnect feature and rounded tie plate inlet	Top Nozzle without a quick Disconnect feature and without rounded tie plate inlet	AFA 3G [1] equipped with a Quick Disconnect feature and rounded tie plate inlet	–
Bottom Nozzle	FUELGUARD™	FUELGUARD™ [1]	–	–

[1] The loss coefficient for this specific hardware component was either obtained or verified from the pressure drop test results using the prototype fuel assembly.

[2] Multiple prototype fuel assemblies have been used in the Magaly test facility to acquire the measured pressure drops for U.S. EPR fuel assembly design components.

Table 04.02-18 – 2: Component Loss Coefficients for the 2006 U.S. EPR Fuel Assembly Design (without HTP Grid Modifications) Supporting the U.S. EPR FSAR Tier 2 Analyses

Component Description	Loss Coefficient (at 500,000 Re)
Top Nozzle	[ ]
Upper End Grid, HMP	[ ]
Intermediate Grids, HTP	[ ]
Lower End Grid, HMP	[ ]
Bottom Nozzle	[ ]

[1] The loss coefficient for the Top Nozzle is shown with the recoverable loss included. When the [ ] recoverable loss is removed, the unrecoverable loss coefficient is [ ].

[2] The loss coefficient for the Bottom Nozzle is shown with the recoverable loss included. When the [ ] recoverable loss is removed, the unrecoverable loss coefficient is [ ].

Table 04.02-18 – 3: Core Pressure Drop at 100% Full Power for the 2006 U.S. EPR Fuel Assembly Design (without HTP Grid Modifications) Supporting the U. S. EPR FSAR Tier 2 Analyses

Description	Core Pressure Drop (psi)
2006 U.S. EPR Fuel Assembly Design (without HTP Grid Modifications)	[ ]

Table 04.02-18 – 4: Characteristics for the Revised U.S. EPR Fuel Assembly and the Prototype Fuel Assemblies Tested in the Hermes-P and Magaly Loops Supporting the 2013 Revised Loss Coefficient Basis

Description	Revised U.S. EPR Fuel Design	2007 Hermes-P Prototype Assembly	2005 Magaly Prototype Assembly [4]	2005 Magaly Prototype Assemblies [4]
Grid Array	17x17	17x17	17x17	17x17
Intermediate Spacer Grid	HTP (with deburred interior strips) (2 central HTP grids with [ ] and the remaining HTP grids with [ ])	HTP [1] (4 HTP grids with deburring and tumbling and 4 HTP grids with deburring only)	–	HTP [2] (for sensitivities in strip thickness and weld nugget size)
Lower and Upper End Spacer Grids	HMP	HMP	–	HMP [1]
Number of Fuel Rods	265	264	264	264
Fuel Rod Outer Diameter, in	0.374	0.374	0.374	0.374
Fuel Rod Pin Pitch, in	0.496	0.496	0.496	0.496
Number of Guide Tubes	24	24	24	24
Guide Tube Outer Diameter, in	0.490	0.490	0.490	0.490
Number of Instrument Tubes	0	1	1	1
Top Nozzle	AFA 3GL equipped with a Quick Disconnect feature and rounded tie plate inlet	AFA 3GL equipped with a Quick Disconnect feature and rounded tie plate inlet	AFA 3G [1] equipped with a Quick Disconnect feature and rounded tie plate inlet	–
Bottom Nozzle	FUELGUARD™	FUELGUARD™ [1]	–	–

[1] The loss coefficient for this specific hardware component was either obtained or verified from the pressure drop test results using the prototype fuel assembly.

[2] The pressure drop sensitivities in this test were used to establish a component loss coefficient.

[3] WNS = weld nugget size.

[4] Multiple prototype fuel assemblies have been used in the Magaly test facility to acquire the measured pressure drops for U.S. EPR fuel assembly design components.

Table 04.02-18 – 5: Component Loss Coefficients for the 2013 Revised U.S. EPR Fuel Assembly Design Supporting the U.S. EPR FSAR Tier 2 Analyses

Component Description	Loss Coefficient (at 500,000 Re)
Top Nozzle	[ ]
Upper End Grid, HMP	[ ]
Intermediate Grids, HTP (2) Central HTP Grids with Thicker Strips (6) HTP Grids with Larger Weld Nuggets	[ ] [ ]
Lower End Grid, HMP	[ ]
Bottom Nozzle	[ ]

[1] The loss coefficient shown for the Top Nozzle is the unrecoverable loss coefficient.

[2] The loss coefficient shown for the Bottom Nozzle is the unrecoverable loss coefficient.

Table 04.02-18 – 6: Core Pressure Drop at 100% Full Power for the 2013 Revised U.S. EPR Fuel Assembly Design (with HTP Grid Modifications) Supporting the U.S. EPR FSAR Tier 2 Analyses

Description	Core Pressure Drop (psi)
2013 U.S. EPR Fuel Assembly Design (with HTP Grid Modifications)	[ ]

Table 04.02-18 – 7: Summary of 95/95 Minimum Fuel Assembly Hold Down Margins for Normal Operation Statepoints

Statepoint Description	Average Coolant Temperature (°F)	Beginning of Life, BOL (lbs)	Beginning of Cycle 2, BOC2 [1] (lbs)	Beginning of Cycle 3, BOC3 [2] (lbs)	End of Life, EOL (lbs)

[1] Beginning of the second cycle of irradiation for the fuel assembly.

[2] Beginning of the third cycle of irradiation for the fuel assembly.

Figure 04.02-18 – 1: Timeline for Pressure Drop Testing in the Hermes-P and Magaly Loops, Test Reports, and 2006 Loss Coefficient Calculations Supporting the U.S. EPR FSAR Tier 2

Figure 04.02-18 – 2: Timeline for Pressure Drop Testing in the Hermes-P and Magaly Loops, Test Reports, and Loss Calculations Supporting the 2013 Revised Loss Coefficients for the U.S. EPR Fuel Design

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