AREVA

August 23, 2011
NRC:11:091

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Draft Proprietary Presentation Titled "U.S. EPR Design Certification: NRC Review of Fuel Assembly Mechanical Design – Seismic Round 7 RAI"

Ref. 1: Letter, Ronnie L. Gardner (AREVA NP Inc.) to Document Control Desk (NRC), "Request for Review and Approval of ANP-10285P, 'U.S. EPR Fuel Assembly Mechanical Design Topical Report'," NRC:07:051, October 2, 2007.

Ref. 2: Letter, Getachew Tesfaye (NRC) to Sandra Sloan (AREVA NP Inc.), "Seventh Request for Additional Information Regarding ANP-10285P, 'Fuel Assembly Mechanical Design Topical Report'," May 17, 2011.

AREVA NP Inc. (AREVA NP) requested the NRC's review and approval of topical report ANP-10285P, "U.S. EPR Fuel Assembly Mechanical Design Topical Report" in Reference 1. The NRC provided a seventh Request for Additional Information (RAI) regarding this topical report in Reference 2. A meeting will be held with the NRC on August 24, 2011 to discuss the questions contained in Reference 2. A copy of a draft presentation to the NRC titled "U.S. EPR Design Certification: NRC Review of Fuel Assembly Mechanical Design – Seismic Round 7 RAI" is attached.

AREVA NP considers some of the material contained in the attachment to this letter 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. Proprietary and non-proprietary versions of the response are attached.

If you have any questions related to this submittal, please contact me by telephone at 434-832-2369 or by e-mail to sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

Sandra M. Sloan, Manager
New Plants Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: G. Tesfaye
Docket No. 52-020

D077
NRD

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, New Plants Regulatory Affairs for AREVA NP Inc. 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 presentation to the NRC titled "U.S. EPR Design Certification: NRC Review of Fuel Assembly Mechanical Design – Seismic Round 7 RAI" dated August 24, 2011, 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(b) and 6(c) 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 23rd

day of August, 2011.

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2015
Registration Number: 110864

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2015

U.S. EPR Design Certification: NRC Review of Fuel Assembly Mechanical Design – Seismic Round 7 RAI

Sandra Sloan
Gary Williams

NRC – August 24, 2011

EPR™ by AREVA

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Objective and Agenda

- **Objective**
  - **Propose path forward for response to RAI round 7**

- **Agenda**
  - **Background**
  - **Round 7 RAIs**
    - Review of RAI Questions
    - Proposed RAI responses

Background: Fuel Mechanical Faulted Methodology

- ANP-10285P, U.S. EPR Fuel Assembly Mechanical Design Topical Report
  - Identifies applicable methodologies for U.S. EPR fuel assembly mechanical evaluation and demonstrates fuel assembly mechanical design meets acceptance criteria
  - Seismic-LOCA methodology/evaluation is one topic of the report
  - ANP-10285P references BAW-10133PA and Addendum 1 and 2 PA for Seismic-LOCA methodology
- BAW-10133PA and Addendum 1 and 2 PA:
  - BAW-10133PA, Rev. 1 approved June 1986
  - Addendum 1 and 2 PA approved October 2000

NRC Review History

- Oct 2007 - Submittal of U.S. EPR Fuel Mechanical Design Topical Report
- Oct 2009 - First Seismic-Related Questions Received (FSAR Chapter 4)
- Jan 2010 - Audit on Seismic Analyses (no major issues identified)
- Mar 2010 - 6th Round RAIs issued (include seismic questions)
- Apr 2010 - Response to FSAR Chapter 4 questions
- May 2010 - Draft Responses to 6th Round RAIs
- Sep 2010 - Audit on Seismic Analyses (additional details requested on 6th Round RAIs)
- Jan 2011 - Audit on Seismic Analyses (concerns expanded to include EOL grid strength and applicability of linear methodology to U.S. EPR fuel)
- Mar 2011 - Draft 7th Round RAIs (all seismic)
- May 2011 - 7th Round RAIs issued

Summary of Outstanding RAIs Relevant to Fuel Seismic Evaluation

Applicability of Method

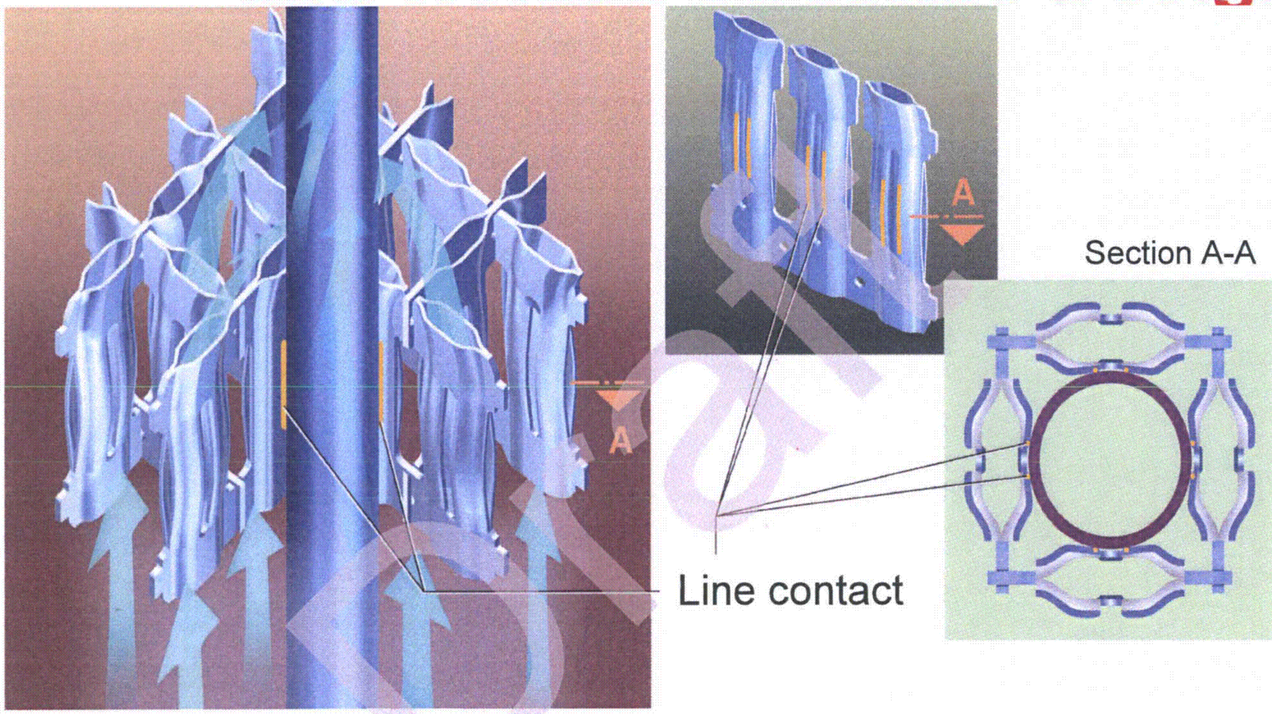
- RAI 64: Applicability of Methodology to U.S. EPR Fuel
- RAI 65: Validate Use of CASAC with U.S. EPR Fuel
- RAI 66: Provide U.S. EPR Fuel Assembly Test Data for (a) Deflections beyond BAW-10133PA and (b) BOL and EOL Conditions

- RAI 67: Address Deviations from BAW-10133PA

Grid Strength and Deformation

- RAI 68: Evaluate U.S. EPR at EOL Conditions (Grid Strength)
- RAI 69: Inelastic Grid Deformation Modeling
- RAI 70: Effect of Inelastic Grid Deformation Inherent in Definition of Grid Strength, P(crit)
- RAI 71: Inelastic Grid Deformation Evaluation Methods

US EPR Uses Existing HTP™ Spacer and Welded Structure Design

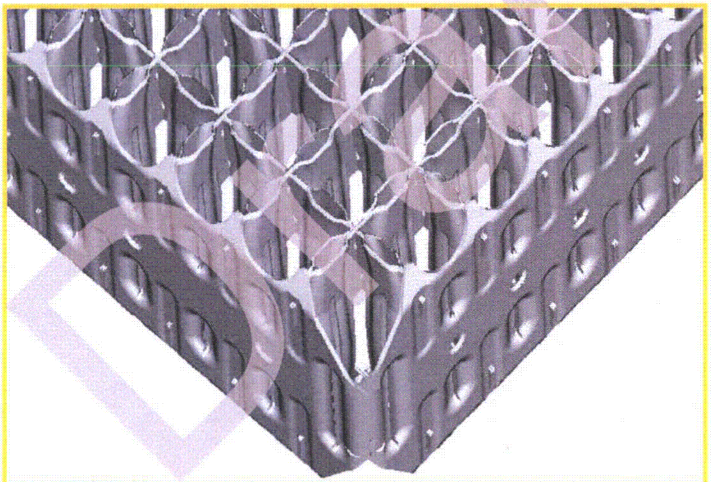


> "Doublet" strip construction
> Dual line contact with fuel rod
> Curved flow channel outlets provide enhanced mixing
> Grids welded to guide tubes
> Robust grid strength
> Effective stiffness and damping characteristics

Draft

HTP™ Is the U.S. PWR Fuel Platform

- **HTP robustness has led to notable success in U.S.:**
  - **All current AREVA fuel customers in U.S. are either using or preparing to transition to HTP fuel**



HTP spacer grids are proven in demanding mechanical conditions

Draft

Start of Proprietary Material

RAI 64: Applicability of Methodology to U.S. EPR Fuel

- **Generic applicability to wide range of PWR designs**
  - **SER for BAW-10133PA states:**
    - "Based on our review, we conclude that the structural analysis methods, including the component representation, ... are acceptable for calculating the fuel system structural response for Mark-C and similar fuel assemblies."
  - **BAW-10133PA itself states:**
    - "A description of the Mark C FA follows to assist in the visualization of the dynamic modeling of the FA. Other B&W designs are similar in concept."
  - **BAW-10133PA Addendum 1 and 2 states:**
    - "The following addendum provides Framatome Cogema Fuels (FCF) with an alternative mechanical faulted condition method, which will eventually be phased in for all fuel assembly designs."
  - **BAW-10133PA is referenced in BAW-10179PA (B&W 177 FA Cycle Reload Analysis Topical)**
  - **The example analysis in BAW-10133PA Addendum 1 and 2 is for the Mark-BW design (a Westinghouse type 17x17 fuel assembly)**
  - **BAW-10172PA and BAW-10239PA provides explicit NRC approval of the seismic methods to the Mark-BW and Advanced Mark-BW fuel assembly designs (Westinghouse type 17x17 fuel assembly)**
  - **A similar version of the NRC approved methodology is used in Europe for both 12 and 14 ft active length AREVA fuel assemblies**

Draft

Comparison of U.S. EPR HTP with BAW-10133 Approved Designs

Parameter	U.S. EPR	Adv. Mk-BW	Mk-C	Mk-B-HTP
Array	17x17	17x17	17x17	15x15
Sq. Envelope (in)	8.426	8.425	8.536	8.536
Assy-to-Assy Gap (in)	.040	.041	0.41	.051
Fuel Rod Pitch	0.496	0.496	0.502	0.568
Length (in)	189.2	159.9	165.7	165.9
Fuel Rod Overall Length	179.1	152.2	152.7	155.0
Effective Grid Span (in)[1]	19.9	21.7	21.8	22.1
Intermediate Grids	8, Zirc HTP	6, Zirc 6-Point Contact	6, Inconel 6-Point Contact	6, Zirc HTP
Fuel Rod OD	.374	.374	.379	.430
GT OD	.490	.482	.465	.530
# of Guide Tubes	24	24	24	16
End Grid Type	2, Inconel HMP	2, Inconel, 6-Point Contact	2, Inconel, 6-Point Contact	Top, Zirc HTP; Bottom, Inconel HMP
Intermediate Flow Mixers	N/A	3 Zirc alloy	N/A	N/A
Intermediate Grid / Guide Tube Connection	Spot welded to guide tubes	Swaged, deflection limiting ferrules	Floating, friction grip on rods/GT	Spot welded to guide tubes

Note 1: All dimensions are nominal

Note 2: Effective grid span is fuel rod overall length divided by number of grid spans

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RAI-64 Planned Response

- **Applicability of methodology to U.S. EPR fuel assemblies**
  - **AREVA's methodology is directly applicable to U.S. EPR:**
    - Summary of NRC approvals and applications to other fuel designs
    - Similarities of U.S. EPR fuel assembly characteristics to those fuel assemblies explicitly approved by the NRC for use with the seismic methodology
    - Methodology not dependent on bundle length
      - Dynamic characteristics are important and are measured for each specific application
      - Lateral gaps constrain motions and are similar for all designs
    - Treatment of fuel assembly frequency characteristics is consistent with other approved methodologies used in industry

Draft

RAI-64: Applicability of Linear Aspects of BAW-10133PA to U.S. EPR

- **Linear model for fuel assembly characteristics (RAI-64)**
  - **SER for BAW-10133PA states:**
    - "Both models [vertical and horizontal] contain non-linear elements required to model non-linear geometry and material conditions present in the core internal design. Examples of such conditions present include gaps, compression only elements, preloaded members, friction and plastic deformation."
    - "This non-linear stiffness is assumed to be of second order for the lateral response calculations."
  - **BAW-10133PA Revision 1, Addendum 1 and 2, section 2.2.2.4 states:**
    - "Fuel assembly frequency and dampening are determined at [ ] inch lateral deflection because it is a conservative approximation (dampening increases with increasing deflection and frequency is an inverse function of deflection)."
      - A single deflection benchmark can appropriately represent the average deflection occurring across the core (i.e., a benchmark at the maximum deflection is not as representative)
  - **Evaluating BOL and EOL bundle frequencies bounds the variation expected as a result of both amplitude and irradiation**
    - [ ] variation in frequency considered

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RAI-64: Applicability of Linear Aspects of BAW-10133PA to U.S. EPR

Fuel Assembly Natural Frequency (1st Cycle) vs Pluck Amplitude

RAI-65: Validate Use of CASAC with U.S. EPR Fuel

- CASAC is the computational tool defined in BAW-10133PA Rev. 1, Addendum 1 and 2
  - CASAC is used in all current designs that reference BAW-10133PA
- BAW-10133PA Revision 1 Addendum 1 and 2 provides a verification of the code CASAC
  - Seven verification cases are provided, including cases based on fuel assembly lateral pluck tests and impact test results
- AREVA's planned response to RAI-65:
  - Validation already provided in BAW-10133PA, Rev. 1, Addendum 1 is extensive and applicable to U.S. EPR fuel
  - BAW-10133PA and CASAC are directly applicable to U.S. EPR, as shown in response to RAI-64
  - No further validation of CASAC is required

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RAI-66(a): Provide U.S. EPR Test Data for Deflections Beyond BAW-10133

- **Fuel assembly characteristics based on testing with an initial [ ] inch amplitude**
  - **BAW-10133PA Revision 1, Addendum 1 and 2, section 2.2.2.4 states:**
    - "Fuel assembly frequency and dampening are determined at **[ ]** inch lateral deflection because it is a conservative approximation (dampening increases with increasing deflection and frequency is an inverse function of deflection)."
  - **The reference amplitude for U.S. EPR fuel is equivalent to existing designs**
    - Maximum deflection amplitude is not related to bundle height
    - Maximum lateral displacement is constrained by available core gap (U.S. EPR inter assembly gap is same as standard W type 17x17 plants)
    - Same basis defined in BAW-10133PA is applicable to U.S. EPR fuel
  - **Variation in frequency considered from [ ] accounts for deflection and irradiation effects**

Draft

- **Deflection and irradiation are accounted for by frequency variation**

RAI-66(a): Provide U.S. EPR Test Data for Deflections Beyond BAW-10133

Fuel Assembly Natural Frequency (1st Cycle) vs Pluck Amplitude

66(a): Provide U.S. EPR Test Data for Deflections Beyond BAW-10133

[ ]

RAI-66(a) Planned Response

- Provide U.S. EPR dynamic test data for deflections beyond BAW-10133PA
  - Additional testing is not required
  - Establishment of current test amplitudes is defined and demonstrated in approved methodology, BAW-10133PA
  - The basis for this test amplitude is applicable to U.S. EPR; there are no significant differences in fuel design or application to impact this
  - AREVA has accounted for the variability of frequency attributed to deflection in a sensitivity study
    - Evaluation defined in response to 6th request for additional information, question 55
    - Study shows that variation in frequency due to deflection or irradiation results in a small variation in grid loads for the U.S. EPR

Draft

RAI-66(b): Provide U.S. EPR Dynamic Test Data for BOL and EOL Conditions

- BAW-10133PA requires that EOL fuel assembly characteristics be considered.
  - "The effect of temperature and irradiation on the mechanical properties of the fuel assembly is considered in the analysis."
  - The topical report section on testing describes the performance of both BOL and EOL fuel assembly characteristic tests.
- The analysis reported in ANP-10285P only considered BOL fuel assembly characteristics
- In response to RAI 55, AREVA performed frequency sensitivity studies to account for EOL fuel assembly characteristics
  - Reduction in frequency to simulate EOL characteristics supported by empirical dynamic test experience with existing fuel designs
  - Reduction in frequency to simulate EOL behavior supported by lateral stiffness tests/analysis of BOL and EOL U.S. EPR representative design
  - The method used in Europe defines the EOL condition as a reduction in frequency from BOL for a given amplitude of [ ]

Draft

RAI-66(b): Basis for Current U.S. EPR EOL Evaluation

- Simulated EOL characteristics in U.S. EPR fuel based on testing with existing designs
  - BOL and EOL dynamic test data up to [ ] inches of deflection:
    - 14x14, 15x15, 16x16, and 17x17 HTP
    - 11, 12, and 13ft active lengths
  - BOL and E ateral stiffness testing on U.S. EPR representative fuel up to [ ] inches
  - Lateral stiffness testing on unirradiated and irradiated ~14ft fuel of different designs including HTP up to [0.8] inches
  - Stiffness and frequency are related
- Common trends can be derived between BOL and EOL frequencies for existing HTP designs
- Maximum reduction of [ ] EOL frequency relative to BOL bounds that determined U.S. EPR HTP

Draft

BOL and EOL FA Frequency vs Amplitude Characteristics

Fuel Assembly Natural Frequency (1st Cycle) vs Pluck Amplitude

RAI-66(b) Planned Response

- AREVA will respond to option iii in the RAI to provide justification for why requested information is not necessary
- EOL frequency response is adequately addressed
  - Methodology requires that effects of irradiation be addressed
  - AREVA has addressed effects of irradiation based on EOL stiffness testing performed on a U.S. EPR representative bundle and the body of knowledge from existing designs within the HTP family
  - Study shows that variation in frequency due to deflection or irradiation results in a small variation in grid loads for the U.S. EPR

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RAI-67: Address Deviations from BAW-10133PA

- Deviations from the NRC approved methodology in BAW-10133PA were used for the U.S. EPR analysis
  - Modal versus Rayleigh dampening
  - Use of only BOL fuel assembly characteristics
  - Forced vibration versus pluck test
  - Combination of loads inconsistent with Regulatory Guide 1.92
- Comprehensive review of design report and methodology has been performed to confirm that all deviations have been identified

Draft

RAI-67: Address Deviations from BAW-10133PA

- **Modal versus Rayleigh dampening**
  - BAW-10133PA specifies the use of Rayleigh damping
  - ANP-10285P analysis uses modal damping
  - Use of modal damping has been evaluated and shown to be conservative
  - Resolution: AREVA will perform evaluations using the approved Rayleigh damping technique
- **Use of only BOL fuel assembly characteristics**
  - BAW-10133PA requires consideration of the effects of irradiation
  - Resolution: AREVA has evaluated U.S. EPR fuel with consideration of EOL characteristics
  - EOL testing addressed by RAI 66

Draft

RAI-67: Address Deviations from BAW-10133PA

- **Forced Vibration versus Pluck Test**
  - **BAW-10133PA requires the performance of both a pluck test and forced vibration test to provide data for a given fuel design**
    - Model benchmark at [ ] deflection based on pluck test
  - **Only a forced vibration test was used to determine dynamic characteristics of U.S. EPR fuel**
    - Forced vibration test was performed at the required amplitude of [ ]
  - **Force vibration testing is appropriate and in some cases, advantageous**
    - Response of the bundle is closer to a true single mode response than it is with free oscillations (i.e., pluck test)
    - In a forced vibration test, a given vibration amplitude can be maintained over a longer period of time, whereas a target frequency/amplitude in a pluck test can only be met once (i.e., single oscillation)
    - Results can be used to determine higher order mode frequency responses
  - **Resolution: AREVA will provide justification for the use of forced vibration test only for the U.S. EPR fuel design**

Draft

RAI-67: Address Deviations from BAW-10133PA

- Combination of loads in accordance with Regulatory Guide 1.92
  - BAW-10133PA states that the methodology is in conformance with Regulatory Guide 1.92
  - Detailed evaluation indicates that the approach used for U.S. EPR was not conservative relative to Regulatory Guide 1.92
  - Issue addressed in response to 6th request for additional information, question 53
  - Resolution: Loads for U.S. EPR will be recalculated in accordance with Regulatory Guide 1.92

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Background Fuel Assembly Seismic Criteria and Grid Deformation

- Regulatory requirement is that a coolable geometry and control rod insertability be maintained.
  - SRP 4.2 Appendix A allows for grid deformation
- SRP 4.2 Appendix A: "The consequences of grid deformation are small. Gross deformation of grids in many PWR assemblies would be needed to interfere with control rod insertion during an SSE (i.e., buckling of a few isolated grids could not displace guide tubes significantly from their proper location), and grid deformation (without channel deflection) would not affect control blade insertion in a BWR. In a LOCA, gross deformation of the hot channel in either a PWR or a BWR would result in only small increases in peak cladding temperature. Therefore, average values are appropriate, and the allowable crushing load P(crit) should be the 95- percent confidence level on the true mean as taken from the distribution of measurements on unirradiated production grids at (or corrected to) operating temperature."

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Determination of P(crit)

Background: Fuel Assembly Seismic Criteria and Grid Deformation

- BAW-10133PA, Revision 1 describes the evaluation of a coolable geometry and control rod insertability
  - Loads below P(crit)
  - Loads above P(crit)
- BAW-10133PA, Revision 1 is already approved for both grid deformation at the point of P(crit) and for grid deformation beyond P(crit)

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Fuel Assembly Seismic Criteria and Grid Deformation

- **ANP-10285P Design Criteria under External Forces:**
  - "OBE – Allow continued safe operation of fuel assembly following an OBE event by establishing that the fuel assembly components do not violate their dimensional requirements."
  - "SSE – Establish safe shutdown of the reactor by maintaining the overall structural integrity of the fuel assemblies, control rod insertability, and a coolable geometry within the deformation limits consistent with the emergency core cooling system (ECCS) and safety analysis."
  - "LOCA or LOCA + SSE – Establish safe shutdown of the reactor by maintaining the overall structural integrity of the fuel assemblies and a coolable geometry within deformation limits consistent with the ECCS and safety analysis."
  - Consistent with BAW-10133PA and SRP Chapter 4.2, Appendix A

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RAI-68: Evaluate U.S. EPR at EOL Conditions (Grid Strength)

- **U.S. EPR grid strength based on BOL conditions**
  - **Consistent with Standard Review Plan Chapter 4.2 Appendix A and approved methodology, BAW-10133PA**

- **AREVA will evaluate U.S. EPR grid strength at BOL and EOL conditions**
  - **AREVA has conducted simulated EOL grid strength testing on U.S. EPR fuel**
    - Simulated EOL conditions based on [testing relaxed grids at room temperature analytically adjusted to hot conditions]
      - [Test grids sized to simulate spring relaxation due to irradiation]
      - [Cold testing simulates increased strength due to material irradiation effects]
  - **AREVA will apply limiting strength values in analysis**

Draft

RAI-69: CASAC Modeling of Grid Deformation

- Current CASAC code has ability to model plastic deformation
  - Consistent with approved methodology, BAW-10133PA
- AREVA response will:
  - Include as necessary evaluation of plastic deformation of grids
  - Provide a discussion on how coolability and control rod insertion are evaluated
  - BAW-10133PA addresses coolability and control rod insertion

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RAI-70: Effect of Inelastic Grid Behavior Inherent in Definition of P(crit)

- RAI requests evaluation of the effects of small deformations inherent in the definition of P(crit)
- BAW-10133PA defines the spacer grid limits in Section 3 of the topical report
  - The grid strength definition is consistent with SRP 4.2 Appendix A
- P(crit) is defined as in SRP Appendix A and in NUREG/CR-1018
  - P(crit) is the allowable crushing load
  - NUREG/CR-1018 acknowledges that this crushing load will entail a small amount of plastic deformation
  - P(crit) is not an elastic limit
- AREVA plans to continue to use established definition of P(crit)

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RAI-71: Coolability and Control Rod Insertion

- **BAW-10133PA addresses coolability and control rod insertion for a deformed grid**
  - Flow area reduction estimated based on maximum credible deformation consistent with SRP 4.2 Appendix A
  - Estimate of peak cladding temperature impact
  - Evaluation of guide tube capability to accept control rod insertion

- **AREVA response will:**
  - Estimate flow area reduction
  - Estimate flow area reduction impact on peak cladding temperature
  - Demonstrate that control rods necessary for safe shutdown can be inserted

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Summary and Next Steps

- **Response strategies proposed for round 7 RAIs**
  - **Proposed responses will account for**
    - Minimum grid strength from BOL and EOL conditions
    - Combination of loads in accordance with Reg. Guide 1.92
    - Use of Rayleigh damping
  - **Sensitivity studies to account for variations in frequency due to irradiation and deflection amplitude**
  - **Proposed responses will support the applicability of BAW-10133PA to the U.S. EPR and will be consistent with SRP**
- **Next steps**
  - **Establish timing for follow-up interactions**
  - **AREVA to provide schedule for RAI responses**

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