AREVA NP

ANP-10337P-000
Audit #1

AREVA / NRC
February 8-9, 2017

AREVA

Agenda

- Meeting objectives
- Overview of topical report
- Review of Chapters 1 through 4
  - At the conclusion of each chapter, material is included to address "NRC Comments" relative to the 11/15/2016 email transmittal from Jonathan Rowley (file "Seismic_Requirements_Criteria.r2.docx")
- Errata and Clarifications
- Source Reference Files for Review
- Data Needs for Future Review
- Next steps – Planning for 2nd Audit

Objectives

- Reach an understanding of the following topics pertaining to ANP-10337P-000:
  - Applicability
  - Regulatory Requirements
  - Establishment of Acceptance Criteria
- Develop actions for addressing errata and clarifications relevant to ANP-10337P-000
- Discuss future review activity

Topical Report Outline

Audit #1 Focus

- Introduction
  - Purpose, method overview, and summary of sections
- Applicability
  - PWR Generic with specific requirements for grid behavior
- Regulatory Requirements
  - Summary of regulatory requirements that are applicable to this topical
- Acceptance Criteria
  - Interpretation of regulatory requirements to establish conservative acceptance criteria
  - OBE, SSE, LOCA, SSE+LOCA
  - Grids, Non-grid components
- Model Architecture
  - Generic vertical and lateral model architecture for PWRs
- Definition of Model Parameters and Allowables
  - Design and plant specificity is introduced
  - Fuel Characterization Testing / Plant Geometry / Time History Inputs
- Seismic and LOCA Analysis
  - Horizontal and Vertical Seismic and LOCA / Combination of SSE and LOCA / Sensitivity Study
- Non-grid Component Evaluation
  - Load Combination
  - Evaluation of fuel assembly deflection shapes from horizontal analysis

Topical Report Outline (Appendices)

- **Code description (CASAC)**
  - Description and V&V for code
- **Sample problem**
  - Demonstration of application of methodology to a general PWR fuel design
- **Fuel assembly damping**
  - Test data and processing to establish fuel assembly damping values in flowing water in both non-irradiated and irradiated conditions
- **Simulation of effects of irradiation in fuel assembly testing**
  - Discussion of the various effects of irradiation on the fuel assembly structural response
  - Establishment of protocol used to simulate effects of irradiation
  - Presentation of test data to support protocol
- **Methodology for evaluating effect of grid deformation on ECCS coolability analyses**
- **Justification for use of Level C stress limits to ensure guide tube functionality**

Audit #1 Focus

Chapter 1: Introduction Review

Introduction

- **ANP-10337P-000 is centered around NUREG-0800, Chapter 4.2, Appendix A**
  - Topical report does not address SRP Chapter 3
  - Topical report addresses fuel assemblies and does not address requirements for other equipment (i.e. piping, pumps, RPS, etc.)
- **ANP-10337P-000 largely consolidates content from BAW-10133PA and related Addenda**

Introduction

▶ Notable updates in ANP-10337P-000:

- Methodology for evaluating fuel in irradiated condition
- Augmentation of fuel assembly damping to consider irradiated condition
- Definition of spacer grid allowable in irradiated and non-irradiated condition
- Update protocol of benchmarking fuel assembly dynamic characteristics from tests
- Update methodology for calculating non-grid component loads and stresses
- Update acceptance criteria for guide tube stresses under LOCA and SSE
- Clarification of vertical model
- Clarification on methodology for combining loads from horizontal and vertical analyses
- Implementation of generalized proportional damping in the analysis as an alternative to Rayleigh damping

Chapter 2: Applicability Review

Applicability

- The proposed methodology is applicable to fuel assembly designs for Pressurized Water Reactors
  - PWR fuel designs share a similar geometry and structure
  - Architecture of the numerical models defined in this methodology is appropriate and generic to PWR fuel designs

Applicability

Why is it generically applicable?

- **Design specificity introduced through design characterization testing necessary to define models**
- **Plant specificity introduced through reactor geometry and excitation input**

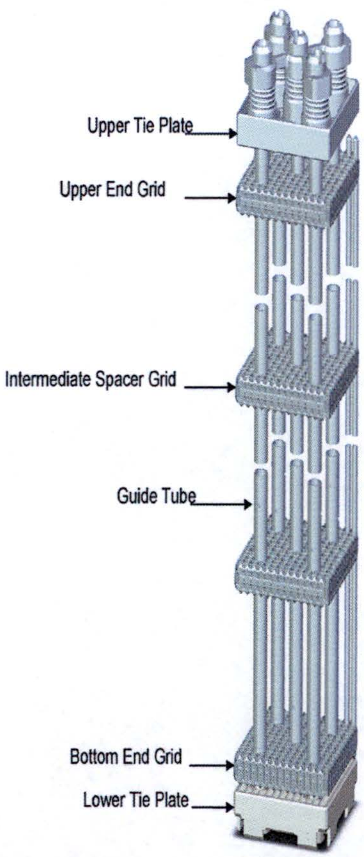
Applicability

▶ Typical PWR Fuel Assembly Characteristics

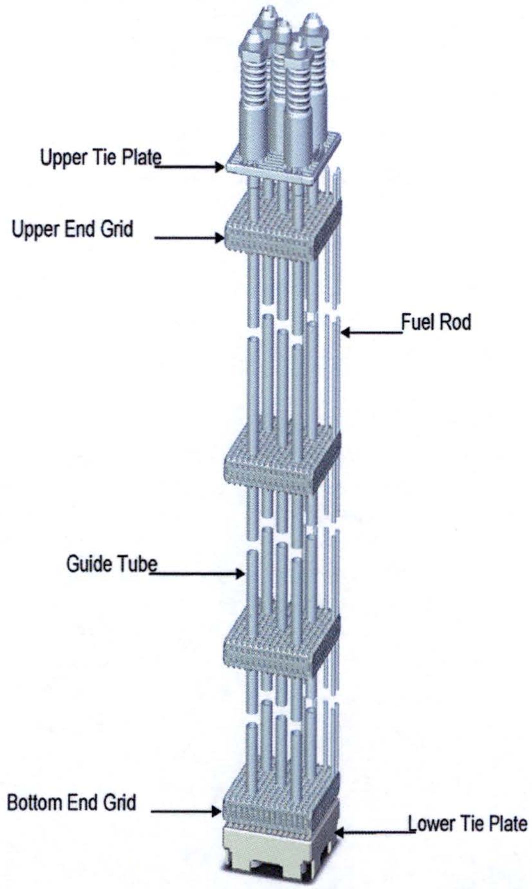
Component	Combustion Engineering			Westinghouse			Babcock & Wilcox	
	14x14	15x15	16x16	14x14	15x15	17x17	15x15	17x17
Guide Tubes	4	0	4	16	20	24	16	24
Guide Bars	0	8	0	0	0	0	0	0
Fuel Rods	176	216	236	179	204	264	208	264
Instrumentation Tube	1	1	1	1	1	1	1	1
Total number of Grids	9	10	11	7	10	11	8	10
Intermediate Spacer Grids	7	8	9	5	5	6	6	8
Intermediate Flow Mixers	0	0	0	0	3	3	0	0
Upper End Grid	1	1	1	1	1	1	1	1
Lower End Grid	1	1	1	1	1	1	1	1
Assembly Overall Length (in)	146 to 157	149	178	161	161	161	166	166
Top Nozzle Hold-Down Spring	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Applicability

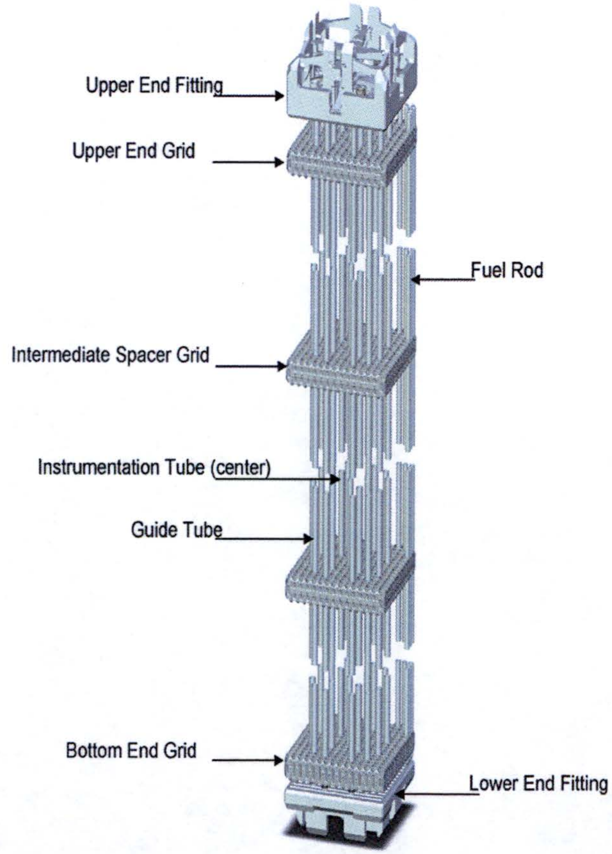
Combustion Engineering 14x14



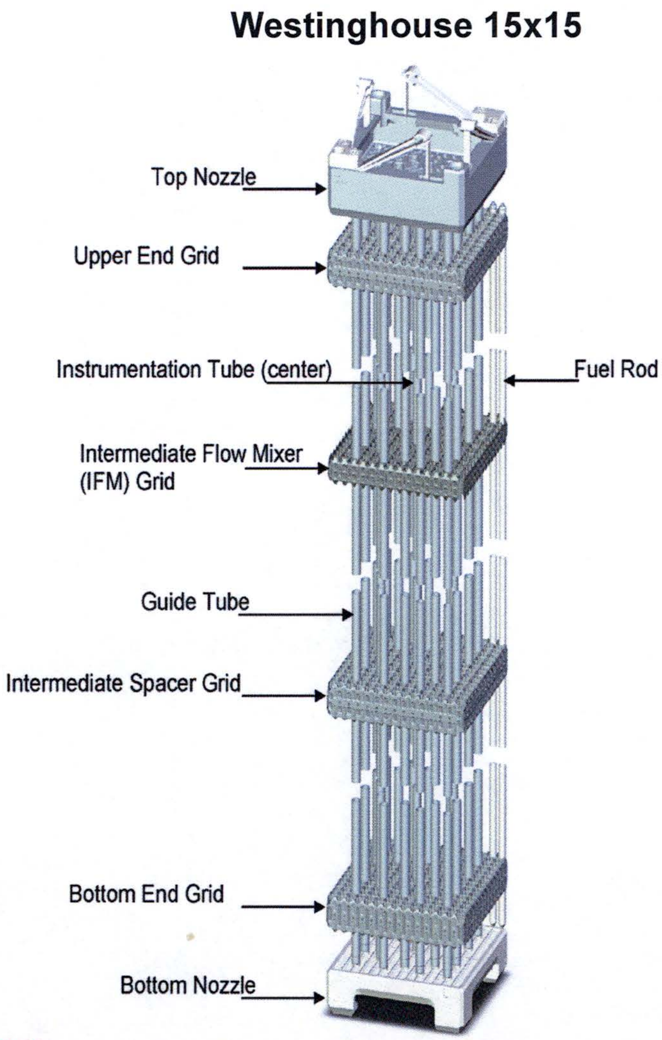
Combustion Engineering 16x16

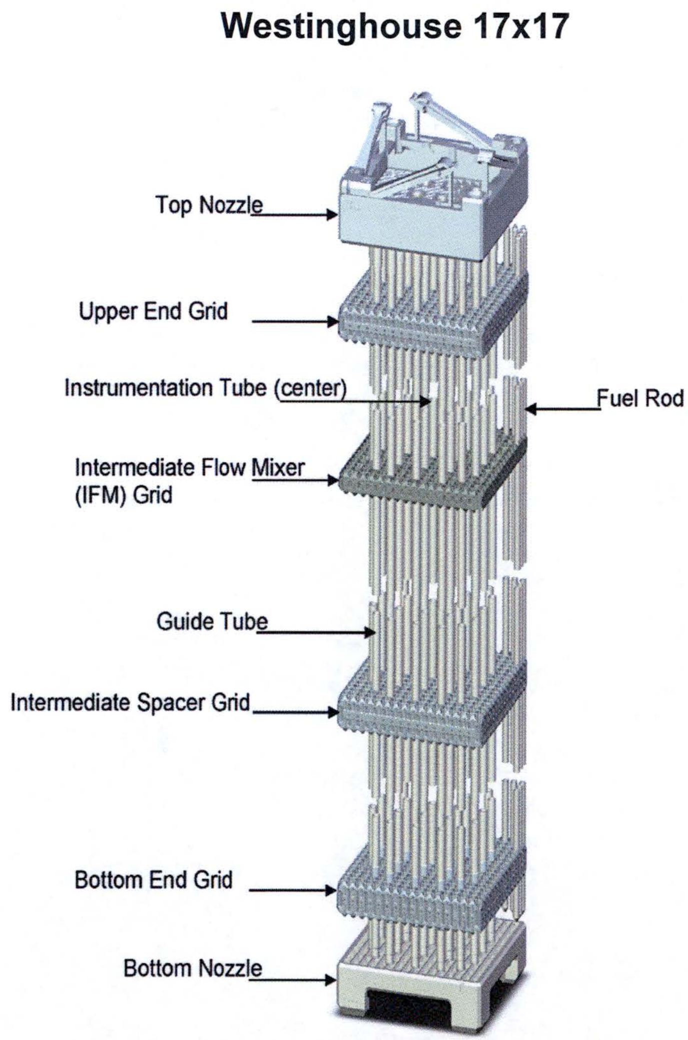


Babcock & Wilcox 15x15



Applicability





NRC Comment

2.0 Safe Shutdown Earthquake, Item 7

Section 2.1 briefly describes the unique features (i.e., guide bars) found at Palisades and states that the same numerical models could be used to represent these features as used to assess the guide tubes. More specificity is needed? Need to understand how these guide bars are currently addressed and what changes are being proposed.

AREVA: Figure 5-2 of ANP-10337P defines the single assembly model. In this model, the cross-sectional geometry of any PWR fuel is homogenized into a single beam representation. The homogenized cross-section does account for actual cross-sectional properties such as area, moment of inertia, etc. The actual structure of the Palisades bundle (i.e. external guide bars welded at each grid location) results in a relatively stiff bundle with a high natural frequency. This global dynamic attribute is captured in the dynamic response of the bundle which is assessed in the free and forced vibration testing. The global dynamic characteristics of the Palisades bundle is reflected in the relatively high rotational stiffness values that will result from model benchmarking. Therefore, the model in Figure 5-2 is capable of representing the dynamic response of a CE15 bundle in the same way that it can represent any other geometry for existing PWR fuel designs.

The vertical model architecture is shown in Figure 5-7 of ANP-10337P. The difference between guide bars and tubes is captured in the cross-sectional properties of those components, but they can both be structurally represented using the same form, regardless of their radial location in the assembly.

Chapter 3: Regulatory Requirements Review

Regulatory Requirements Overview

- 10 CFR 50, Appendix A
  - General Design Criteria
- 10 CFR 50, Appendix S
  - Earthquake Engineering
- 10 CFR 50.46
  - Acceptance criteria for ECCS

- NRC Guidance; NUREG-0800, Chapter 4.2
  - Fuel System Design

Regulatory Requirements

- 10 CFR 50, Appendix A: Basic design criteria to be addressed in accident analysis methodology
  - GDC 2: Design to consider severe natural phenomena, appropriate combination of the effects of normal and accident conditions with the effects of natural phenomenon, and reflect the safety functions to be performed
  - GDC 27: Maintain control rod insertability (reactivity control) under postulated accident conditions
  - GDC 35: Prevent fuel rod fragmentation and maintain ECCS coolability during and after LOCA

Regulatory Requirements

- **10 CFR 50, Appendix S: Implements GDC 2 as it pertains to seismic events**
  - Defines Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE)
  - OBE
    - Unrestricted operation following an OBE
    - Reactor shut-down at motions above OBE
      - 4 hrs. typically allowed for evaluation (Reg. Guide 1.166)
      - Analogous to time intervals for operations outside LCOs
    - Explicit response or design analysis not performed if OBE severity is 1/3 or less of the SSE severity
  - SSE
    - Treated independently
    - Demonstrate integrity of the reactor coolant pressure boundary, capability to shut down reactor and maintain it in a safe-shutdown condition, and capability to prevent or mitigate consequences of offsite exposures

Regulatory Requirements

- **Consideration of SSE plus AOOs is not required from the regulatory requirements for AOOs (GDC 10)**
  - **Appendix S criteria clearly define a design basis event that is beyond normal operating conditions**
  - **Appendix S clearly defines requirement to shut down reactor**
    - Elsewhere, a period of time is allowed, post-earthquake, to assess condition
    - This is analogous to allowances for time outside of LCOs
    - Operation following an earthquake above OBE is not allowed
  - **SRP (Chapter 4.2, Section I) defines requirement that fuel system is not damaged as a result of normal operation including AOOs**
    - SRP defines "not damaged": fuel rods do not fail, dimensions remain within operational tolerances, and functional capabilities are not reduced
    - SSE event is not analyzed with the same definition of "not damaged"
  - **Consideration of LOOP with an SSE is considered for conservatism in accounting for flow-induced damping**

Combination of SSE with AOOs is contrary to regulatory framework

Regulatory Requirements

- **10 CFR 50, Appendix S: Implements GDC 2 as it pertains to seismic events**
  - Safety requirements for relevant structures, systems, and components (SSCs) during and after SSE
    1. Maintain integrity of reactor coolant boundary
    2. Demonstrate ability to shut down reactor and maintain it in a safe-shutdown condition
    3. Prevent or mitigate consequences of offsite exposures
  - Emphasizes the requirement to ensure that safety functions (functional integrity, rather than structural integrity) of safety-related SSCs must be assured during and after SSE

Permissible to design for strain limits in excess of yield strain, provided that safety functions are maintained

Regulatory Requirements

- **10 CFR 50.46: Provides details required to implement GDC 35**
  - Defines limits for peak cladding temperature, maximum cladding oxidation, and maximum hydrogen generation in cladding
  - Establishes requirement to maintain coolable geometry in the core during and after a LOCA event
  - Any deformation in the fuel assembly resulting from a LOCA event must be considered in the analysis

Regulatory Guidance

- Appendix A of Chapter 4.2 of NUREG-0800 (Standard Review Plan)
- LOCA
  (1) "fuel rod fragmentation must not occur as a direct result of blowdown loads"
    - Satisfied if combined loads on fuel rods and components other than spacer grids remain below acceptable loads
  (2) "10 CFR 50.46 temperature and oxidation limits must not be exceeded"
    - Satisfied by an ECCS analysis
    - If grid loads are below P(crit), the usual ECCS analysis is sufficient
    - If grid loads are above P(crit), then grid deformation must be assumed in ECCS analysis
      - An assumption of maximum credible deformation may be made (i.e. fully collapsed grid)
  (3) Control rod insertability must be demonstrated for combined load of worst-case LOCA plus SSE
    - If grid loads are below P(crit), then significant deformation would not be present to interfere with control rod insertion
    - If grid loads are above P(crit), then additional analysis required to demonstrate that deformation does not prevent control rod insertion
- LOCA conservatively combined with SSE to establish limiting design basis conditions
  - Satisfies GDC2 requirement for "appropriate" combination of accident conditions with the effects of natural phenomena (SRP 4.2, Appendix A (II)(5))
    - This is conservative since there is no phenomenological connection between SSE and LOCA

Regulatory Guidance

- Appendix A of Chapter 4.2 of NUREG-0800 (Standard Review Plan)
- SSE
  (1) "fuel rod *fragmentation* must not occur as a result of the seismic loads"
    - Same criteria as LOCA

  (2) Control rod insertability must be assured
    - Same criteria as LOCA
    - Satisfied by SSE + LOCA evaluation, unless licensing basis does not require combined loads
- Criteria for SSE can be satisfied by combined SSE+LOCA analysis

Regulatory Guidance

▶ Grid Strength Criteria

- P(crit) = critical load of the spacer grid
- Consequences of grid deformation are small
  - Gross deformation in many PWR assemblies need to interfere with control rod insertion
  - Gross deformation of hot channel would only result in small increases in peak cladding temperature
  - Therefore, average values are appropriate
- P(crit) should be the 95% confidence limit on the true mean of a sample of grids at or corrected to operating temperature

- NUREG/CR-1018 "Review of LWR fuel system mechanical response with recommendations for component acceptance criteria" provides background on grid strength definition for SRP 4.2 Appendix A

Regulatory Guidance

▶ Acceptance Criteria for Non-grid Components

- Strengths may be deduced from fundamental material properties or experimentation
- Protect against structural failure
- Acceptable loads may follow ASME Code guidance
- Acceptable loads should consider buckling and fatigue effects

Guide tubes require a criteria that ensures safety functionality is not challenged

NRC Comment

1.0 Operating Basis Earthquake, Opening Statement

Table 1 summarizes the OBE regulatory requirements and acceptance criteria used to demonstrate compliance. The OBE is not a postulated accident and is expected to occur during the lifetime of the reactor. Furthermore, plants are not required to shut down following a seismic event up to the OBE ground motion, and may restart (without NRC involvement) if tripped on other signals during the event (e.g., loss of switchyard or offsite power).

AREVA:

We agree that OBE is not a postulated accident. However, the regulations do not state that an OBE is expected to occur during the lifetime of the reactor. The definition of OBE in Appendix S is:

"The vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public will remain functional."

There is no mention of frequency of occurrence. An OBE is not an AOO; seismic events are their own category.

NRC Comment

1.0 Operating Basis Earthquake, Item 1

SRP 3.9.3 describes Service Level B loading combinations: sustained loads + system operating transients + OBE. Section 3.1.2 states that for "OBE events with a severity greater than 1/3 of SSE ground motion, an analysis must be performed, in combination with normal operating loads, to demonstrate that all SSCs …" It is not clear whether system operating transients are covered, or need to be covered.

AREVA:

This topical report does not address Chapter 3 issues. The focus of the topical report is to evaluate the performance of the fuel under seismic and LOCA. The performance of the other plant equipment is outside the scope of the topical report. This report addresses SRP Chapter 4.2 Appendix A requirements.

The evaluation of fuel for combined normal operating conditions is outside of the scope of this methodology. This topical does not address the general requirements for performing normal operating evaluations of fuel components.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

Section 3.1.2 states, "… regulatory requirements clearly specify that fuel rod failures, defined as a loss of the fuel rod hermeticity, are permitted during postulated accidents and must be accounted for in the dose analysis". Section 3.1.4 goes on to state, "… by establishing conservative criteria that prevent fuel rod fragmentation, this conservatively addresses the requirements regarding the radiological consequences of design basis accidents ..."

a. Staff disagrees that preventing fuel rod fragmentation equates to preserving fuel rod hermeticity. Preventing fuel rod fragmentation preserves a coolable geometry (by maintaining rod bundle array), similar to approach for LOCA (50.46) and RIA.

b. Staff agrees that SSE is a postulated accident. As such, loss of fuel rod hermeticity is allowable, provided offsite and on-site doses have been shown to meet acceptance criteria.

c. If either (1) control rod insertion scram times are extended due to guide tube distortion or (2) significant permanent grid deformation occurs (changing local TH conditions), then the applicant must address the potential for DNB/CHF related fuel rod failures and any associated radiological consequences.

d. 10CFR50.46(b)(4) requires that any calculated changes in core geometry be specifically addressed. When addressing SSE+LOCA, it must be demonstrated that ECCS performs its intended function under the combined loads and any predicted grid deformation. Same philosophy applies to other safety systems. As such, any significant SSE grid deformation must demonstrate that other safety systems perform their intended function under accident conditions.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

AREVA:

The topical report ANP-10337P applies only to fuel assemblies. Appendix S applies to all SSCs that are necessary for specific functions. This topical report only addresses Appendix S as it applies to fuel assemblies. The requirements for fuel assemblies are specified in Chapter 4.2 Appendix A.

SRP Chapter 4.2 II.1.B.viii (points to Appendix A) and Chapter 4.2 Appendix A define the fuel failure criterion for fuel rods for an SSE as fuel fracture/fuel fragmentation. To prevent fuel fracture/fuel fragmentation ANP-10337P limits the stress on the fuel rod during an SSE so that it does not fail. This also assures coolability.

The SRP Chapter 4.2 Appendix A does not state a radiological criterion for an SSE, but since the fuel rod does not fail from the only failure criterion specified this implies that there is no radiological consequence.

An SSE is a unique event which shares some characteristics with Postulated Accidents (PAs) but the criteria that are often associated with PAs are not specified for an SSE.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

Section 3.1.2 states, "… regulatory requirements clearly specify that fuel rod failures, defined as a loss of the fuel rod hermeticity, are permitted during postulated accidents and must be accounted for in the dose analysis". Section 3.1.4 goes on to state, "… by establishing conservative criteria that prevent fuel rod fragmentation, this conservatively addresses the requirements regarding the radiological consequences of design basis accidents ..."

> **a. Staff disagrees that preventing fuel rod fragmentation equates to preserving fuel rod hermeticity. Preventing fuel rod fragmentation preserves a coolable geometry (by maintaining rod bundle array), similar to approach for LOCA (50.46) and RIA.**

AREVA:

SRP Chapter 4.2 II.1.B.viii (points to Appendix A) and Chapter 4.2 Appendix A define the fuel failure criterion for fuel rods for an SSE as fuel fracture/fuel fragmentation. To prevent fuel fracture/fuel fragmentation ANP-10337P limits the stress on the fuel rod during an SSE so that it does not fail. This also assures coolability.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

Section 3.1.2 states, "… regulatory requirements clearly specify that fuel rod failures, defined as a loss of the fuel rod hermeticity, are permitted during postulated accidents and must be accounted for in the dose analysis". Section 3.1.4 goes on to state, "… by establishing conservative criteria that prevent fuel rod fragmentation, this conservatively addresses the requirements regarding the radiological consequences of design basis accidents ..."

> **b. Staff agrees that SSE is a postulated accident. As such, loss of fuel rod hermeticity is allowable, provided offsite and on-site doses have been shown to meet acceptance criteria.**

AREVA:

The SRP Chapter 4.2 Appendix A does not state a radiological criterion for an SSE, but since the fuel rod does not fail from the only failure criterion specified this implies that there is no radiological consequence.

An SSE is a unique event which shares some characteristics with Postulated Accidents (PAs) but the criteria that are often associated with PAs are not specified for an SSE.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

Section 3.1.2 states, "… regulatory requirements clearly specify that fuel rod failures, defined as a loss of the fuel rod hermeticity, are permitted during postulated accidents and must be accounted for in the dose analysis". Section 3.1.4 goes on to state, "… by establishing conservative criteria that prevent fuel rod fragmentation, this conservatively addresses the requirements regarding the radiological consequences of design basis accidents ..."

c. If either (1) control rod insertion scram times are extended due to guide tube distortion or (2) significant permanent grid deformation occurs (changing local TH conditions), then the applicant must address the potential for DNB/CHF related fuel rod failures and any associated radiological consequences.

AREVA:

An SSE is a unique event which shares some characteristics with Postulated Accidents (PAs) but the criteria that are often associated with PAs are not specified for an SSE.

The fuel assembly criteria for an SSE are clearly specified in Chapter 4.2 Appendix A.

- **Control rod drop time is not a criterion (though Level C assures that the control rod drop time is not impacted)**
- **DNB/CHF is not a criterion**
- **Radiological consequence is not a criterion**

Spacer grid deformation has been allowed for an SSE since Appendix A was first published and these criteria were not required.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 2

Section 3.1.2 states, "… regulatory requirements clearly specify that fuel rod failures, defined as a loss of the fuel rod hermeticity, are permitted during postulated accidents and must be accounted for in the dose analysis". Section 3.1.4 goes on to state, "… by establishing conservative criteria that prevent fuel rod fragmentation, this conservatively addresses the requirements regarding the radiological consequences of design basis accidents ..."

> d. 10CFR50.46(b)(4) requires that any calculated changes in core geometry be specifically addressed. When addressing SSE+LOCA, it must be demonstrated that ECCS performs its intended function under the combined loads and any predicted grid deformation. Same philosophy applies to other safety systems. As such, any significant SSE grid deformation must demonstrate that other safety systems perform their intended function under accident conditions.

AREVA:

10CFR50.46(b)(4) only applies to LOCA.

The current SRP 4.2 guidance of ensuring control rod insertion and preventing fuel rod fragmentation satisfies the requirements of GDC 2 and 10CFR50 Appendix S. This guidance has been implemented into the licensing bases of currently operating plants. There are no further regulatory requirements to address grid deformation during an SSE.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 3

Section 3.1.2 summarizes Appendix S and states, "Accident induced load conditions caused by seismic events will be accounted." This statement does not exist in Appendix S. Appendix S implies, as GDC-2 explicitly requires, that accident loads are combined with seismic loads. These postulated accidents are independent of the seismic event (i.e., not caused by the seismic motion).

AREVA:

AREVA agrees with the NRC comment and we will revise Section 3.1.2 accordingly.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 4

Because plastic deformation in grid cage and guide tube is allowed (and predicted) at some point above OBE, plants would not be allowed to restart following a seismic event with ground motion above OBE until a complete core inspection was completed. In addition, fuel assembly handling (e.g., lifting for unloading or inspection) may be prohibited.

AREVA:

Post-seismic inspections are outside of the scope of ANP-10337P.

The extent or content of the plant review or basis for re-start approval is defined in RG 1.167 which endorses EPRI NP-6695. The guidance does not say that a complete core inspection is required in this scenario and it does not define any limitations on fuel handling.

- **10 CFR 50.54(ff) states**
  - **"For licensees of nuclear power plants that have implemented the earthquake engineering criteria in Appendix S to this part, plant shutdown is required as provided in Paragraph IV(a)(3) of Appendix S to this part. Prior to resuming operations, the licensee shall demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public and the licensing basis is maintained."**

NRC Comment

3.0 LOCA or SSE+LOCA, Item 4

Section 3.1.4 states, "… it will be shown that the worst-case hydraulic loads from a LOCA event will not cause the fuel assembly to become unconstrained from its indexed position, even under liftoff." Once liftoff is predicted, how is it demonstrated that the degree of bundle movement is less than the length of the core support plate pin?

AREVA:

This check can be performed in an interface evaluation to determine if it is ever possible to become unconstrained in any condition.

For GAIA, this interface evaluation is in [ ]. Appendix 3 shows that the lower core pin length is 1.87 inches, but the available gap between the UTP and upper core plate is [ ] inches. Thus, even with maximum lift-off the bundle cannot become unconstrained.

If this requirement could not be satisfied with an interface evaluation, then the degree of fuel assembly lift-off predicted during a vertical seismic or LOCA event should be compared to the lower core pin length.

[redacted]

Chapter 4: Acceptance Criteria Review

AREVA's Grid Strength Criteria

AREVA's Grid Strength Criteria

▶ OBE:

- Deformation based limit
- Based on residual deformation limits that are the more limiting of:
  - The manufacturing tolerance of grid
  - The critical (buckling) limit of the grid (i.e. P(crit) from NUREG-0800)
- Range of deformation is considered insignificant relative to the as-designed state
  - No effect on ECCS coolability or control rod insertion
- Can be established in the form of a load limit, which corresponds to deformation limit
  - [

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AREVA's Grid Strength Criteria

AREVA's Grid Strength Criteria

- **SSE and LOCA:**

AREVA's Grid Strength Criteria

AREVA's Grid Strength Criteria

AREVA

AREVA's Currently Approved Grid Strength Criteria

AREVA's Grid Strength Criteria Method for Evaluating Coolability

- Covered in Appendix E of ANP-10337P-000
- Primary effect is reduction in flow area
- Assume deformation occurs in hottest assembly
- [ ]
- Heat exchange balance at the fuel rod wall used to calculate PCT rise after deforming grid

$$\frac{q''_{reduc}}{q''_{nom}} = \frac{A_{reduc} \cdot \left(T_{clad,reduc} - T_{coolant}\right)}{A_{nom} \cdot \left(T_{clad,nom} - T_{coolant}\right)}$$

- [ ]

AREVA's Criteria for Components Other than Grids

In general, . . .

for SSE and/or LOCA, component allowables are based on Service Level D limits from the ASME BPV Code,

- Reference: ASME BPVC Section III, Division 1, Appendix F
- Consistent with SRP to apply ASME guidance to protect against structural failure
- Buckling for fuel rods and guide tubes must be evaluated
- A fatigue analysis is not necessary for SSE and SSE + LOCA excitations.
  - By definition, the plant is only analyzed for one of these events

Or derived from ultimate strength testing

- e.g. welded connections, nozzles, etc.

But, there are exceptions. . .

AREVA's Criteria for Components Other than Grids

▶ Exceptions to Service Level D limits:

- All exceptions are more conservative
- OBE:
  - Component allowables based on Service Level B limits
  - Maintain full functionality for normal operation
- Guide Tubes <u>in Control Rod Locations</u>:
  - For SSE and SSE+LOCA, use Service Level C limits plus buckling
  - Ensures functional requirement for control rod insertion and exceeds SRP structural integrity requirements
- Fuel Rods:
  - For SSE and SSE+LOCA, allowable stresses based on 90% irradiated yield value, consistent with SRP 4.2
  - Depends on material selection (e.g. M5®); specific commitments made in material topicals (e.g. M5® topical, BAW-10227PA)

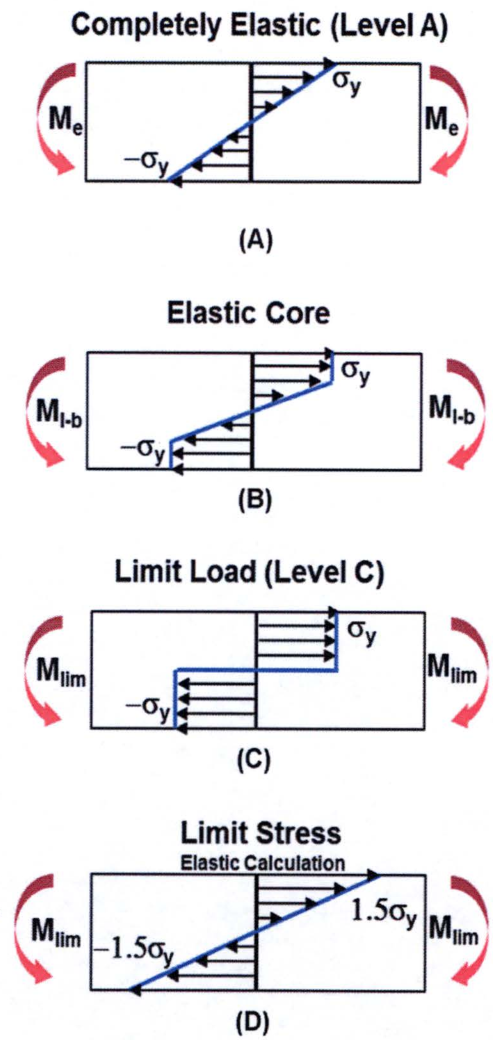
Guide tubes will use a more conservative criteria than what is generally used by the industry

Level C Criteria for Guide Tubes

- Covered in Appendix F of ANP-10337P-000
- Guide tubes must ensure functional (not structural) integrity for control rod insertability
- Level C limits allow for limited plastic strain
  - Consistent with 10 CFR 50 Appendix S

Level C Criteria for Guide Tubes

- ▶ **Level C is boundary between**
  - Loads which can be sustained while ensuring control over deformations, and. . .
  - Load which can be sustained from a structural point of view, but for which the component can not control its own deformation



The limit stress, based on elastic analysis, exceeds the yield stress by a factor that depends on cross-sectional shape (e.g. 1.5 for rectangular cross-sections)

Level C Criteria for Guide Tubes

AREVA

Demonstration of Level C Limit

Demonstration of Level C Limit

Conservatism in Level C Limit

- **Guide tube load re-distribution:**

[ ]

Summary of Acceptance Criteria

NRC Comment

1.0 Operational Basis Earthquake, Item 2

Section 4.2.1 states, [

] This limitation applies to OBE, SSE-only, LOCA-only, and SSE+combined. Need to translate into L&C.

AREVA:

L&C are not necessary since the topical report already addresses this issue.

[

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NRC Comment

1.0 Operational Basis Earthquake, Item 3

Grid cage plastic deformation up to manufacturing tolerances are allowed for OBEs. Allowing OBE loads beyond the elastic region may be problematic given that the fuel design may experience multiple seismic events. How will it deform on the 2nd or 3rd seismic event? Does the [

] remain applicable in the plastic region, especially during subsequent seismic events.

AREVA:

From a technical standpoint, the requirement for [

]

- **The word elastic in the NRC documents on seismic has always been used in a manner that encompassed a degree of plastic deformation, as pointed out in NUREG/CR-1018**
  - "A small amount of permanent deformation is almost always present after grid loading. Settling of the connection strip joints and local deformation due to high local stresses are just two of the possible causes of permanent deformation. Obviously a condition of no permanent deformation must be defined.

    A sufficient condition to demonstrate that no permanent deformation has occurred appears to be that the spacer grid remain within manufacturing tolerances. This condition should be sufficient although possible not necessary because the only meaningful definition of departure from a no-deformed condition would be that deformation which causes a measureable perturbation in the ECCS peak cladding temperature calculation. A manufacturing tolerance criteria should fall within this deformation criteria."
- **NRC comments imply that multiple OBEs should be assumed to occur during the life of a plant (Neither Regulations nor Regulatory Guidance state this)**

NRC Comment

2.0 Safe Shutdown Earthquake, Opening Statement

Table 2 summarizes the SSE regulatory requirements and acceptance criteria used to demonstrate compliance. The SSE is a postulated accident and is not expected to occur during the lifetime of the reactor. Furthermore, plants are required to shut down following a seismic event beyond to the OBE ground motion. According to RG 1.166, licensees are required to analyze ground motion instrumentation within 4 hours and complete a walk-down within 8 hours to determine damage and then bring plant to safe-shutdown conditions.

AREVA:

Note that in Table 2, the NRC states that Level D limits are applied to fuel rods to demonstrate no fragmentation. This is not stated in ANP-10337P. AREVA applies criteria within the guidance of SRP 4.2 (i.e. allowable fuel rod stresses are within 90% of the irradiated yield value).

NRC Comment

2.0 Safe Shutdown Earthquake, Item 1

Section 4.3 states, "… an SSE-only evaluation is only necessary in cases where the licensing basis for the host plant does not require an analysis for combined loads". Staff disagrees. All plants require an SSE-only evaluation. Licensee's may use combined SSE+LOCA loads, provided they meet the potentially more limiting SSE-only criteria. This has historically been the case when plants have reported no significant plastic deformation under combined SSE+LOCA loads.

AREVA:

The exception requiring an SSE-only evaluation would be in situations in which the LOCA event does not require control rod insertion. Otherwise, ANP-10337P does not define more limiting criteria for the SSE-only condition and the SSE-only evaluations are automatically satisfied by SSE+LOCA evaluations. SSE-only evaluations are only required to satisfy control rod insertion and fuel rod fragmentation. SSE+LOCA evaluations have the added requirement of satisfying coolability.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 5

SRP 3.9.3 Appendix A Table 1 provides the following guidance for upset, emergency, and faulted conditions allowed Service Level B, C, and D respectively. It is unclear that the methodology demonstrates operability and functional capability at each Service Level for all components.

> "In addition to meeting the specified service stress limits for given load combinations, operability and functional capability should also be demonstrated as discussed in subsection 2.0 of this appendix and in SRP Section 3.10."

AREVA:

(a) The limits defined in ANP-10337P apply specifically to those fuel components that are listed in Sections 4 and 8. ANP-10337P does not specify any evaluation for operability or functional capability for any components outside of the fuel assembly.

(b) The application of the ASME Service Limits is consistent with the guidance provided by the Standard Review Plan, Section 4.2, including Appendix A, which states that stress limits obtained by methods similar to those given in the ASME code are acceptable.

(c) ANP-10337P applies Level A or B criteria to those fuel components that are required to maintain their operability and functional capability. Given that Level A and B criteria maintain the component within elastic limits, there is no need for further justification. Level A and B limits are applied for OBE events, where continued operation is expected.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 5 (continued)

AREVA:

(d) ANP-10337P applies Level D criteria to those fuel components that are only required to maintain structural integrity. Given that Level D criteria protects against ultimate structural failure of the component, there is no need for further justification. Level D limits are applied for SSE and LOCA events, where safe shutdown is the expectation, rather than continued operation.

(e) Under SSE and LOCA events, guide tubes and related fuel components are unique in that they must maintain safety functionality. This is more limiting than maintaining structural integrity. The justification of Level C limits in this application is addressed in Appendix F of ANP-10337.

NRC Comment

2.0 Safe Shutdown Earthquake, Item 5 (continued)

AREVA:

Component	SSE Safety Function	Service Level Limit
Fuel Rods	Prevent fuel rod fragmentation	N/A
Guide Tubes	Ensure control rod insertability	C
Instrumentation Tube	Structural integrity	D
Top Nozzle	Structural integrity	D
Bottom Nozzle	Structural integrity	D
GT-to-grid connection	Structural integrity	D
GT-to-top nozzle connection	Ensure control rod insertability	C
GT-to-bottom nozzle connection	Structural integrity	D

NRC Comment

2.0 Safe Shutdown Earthquake, Item 6

Section 4.2.1 describes the design criteria and testing used to demonstrate control rod insertion given plastic deformation of the grid cage. Does the methodology need to specifically address multiple assembly control element assemblies (e.g., a single CEDM with rods into more than one assembly), such as found in the CE fleet? In this situation, each assembly may have a different degree of plastic deformation.

AREVA:

[

] It should also be noted that in these cases the assembly-to-assembly gaps can exceed the magnitude of deformation in the guide tube array, thereby providing for the fuel assemblies to align themselves as needed for control rod insertion.

NRC Comment

3.0 LOCA or SSE+LOCA, Opening Statement

Table 3 summarizes the LOCA-only and SSE+LOCA regulatory requirements and acceptance criteria used to demonstrate compliance. These postulated accidents are not expected to occur during the lifetime of the reactor.

AREVA: Note that in Table 3, the NRC states that Level D limits are applied to fuel rods to demonstrate no fragmentation. This is not stated in ANP-10337P. AREVA applies criteria within the guidance of SRP 4.2 (i.e. allowable fuel rod stresses are within 90% of the irradiated yield value).

NRC Comment

3.0 LOCA or SSE+LOCA, Item 1

Section 4.2.1 states, [

] Where has this been shown?

AREVA:

AREVA internal document, [ ], is the source reference to support this statement.

NRC Comment

3.0 LOCA or SSE+LOCA, Item 2

Section 4.2.2.2 states, [

] Where is this demonstration? Applicable to thin walled cylinders?

AREVA:

Appendix F of ANP-10337P summarizes the work performed to arrive at the stated conclusion. AREVA internal document, [ ], is the source reference to support this work.

NRC Comment

3.0 LOCA or SSE+LOCA, Item 3

Section 4.2.2.2 states, "In the case of a LOCA event that does not require control rod insertion, generic service Level D limits can be applied…". Are we positive that regulations (i.e., defense in depth) or long-term cooling assumptions do not require control rod insertability? Given that SBLOCA may require control rod insertion and break sizes (used to assess LOCA loads) are limited by leak before break (LBB), where does this remain applicable?

AREVA:

Appendix A of SRP Chapter 4.2 uses the following language: "Loads from the worst-case LOCA that requires control rod insertion must be combined with the SSE loads, and control rod insertability must be demonstrated for that combined load." The language of the SRP, distinguishes between LOCA events that require and don't require control rod insertability. If this is condition exists within a plant's licensing basis, then Level D limits should be applied.

Some plants do not credit control rod insertion for large-break LOCA for long-term coolability. Furthermore, there are operating plants that do not credit peripheral rod locations for shutdown in LOCA. In these locations, Level D limits should be applied. ANP-10337P also specifies that for fuel assemblies that are not under rodded locations, then Level D is appropriate.

NRC Comment

3.0 LOCA or SSE+LOCA, Item 5

Section 4.2.2 identifies that assembly hold-down springs [ ] . Any exceptions?

AREVA:

Section 4.2.2 addresses the three basic designs for operating PWRs in the U.S. (B&W, W, and CE). In all cases, the hold-down spring [ ]

Fuel Designs

NRC Comment

3.0 LOCA or SSE+LOCA, Item 6

Section 4.2 states, "...1) fuel rod fragmentation does not occur as a result of the blowdown loads…" Why are loads from SSE+LOCA motion and hydraulic blowdown loads not combined?

AREVA:

ANP-10337P does required the consideration of combined SSE + LOCA motion and hydraulics loads. The ANP-10337P methodology includes an axial hydraulic load component that is considered in the vertical analysis. The fuel rod stress evaluations consider the total combined loading from vertical and lateral components.

NRC Comment

3.0 LOCA or SSE+LOCA, Item 7

Appendix E describes how reductions in flow area would be accommodated in ECCS performance analyses.

> **(a) These approximations may be applicable to steady-state heat transfer, but staff has concerns with applicability under LOCA conditions.**

AREVA:

This method is deemed an acceptable approximation for [ ] such as allowed in ANP-10337P.

It is correct to say that the system is not in 'steady state' during a LOCA event. However, the fundamental physics described in Appendix E are still appropriate as heat removal remains the fundamental issue. The simple steady state evaluation provides a conservative approach to this evaluation because the dynamic effects would benefit heat removal.

A transient analysis using a full system code would provide the potential to evaluate the broader effects of grid deformation. However, the connectivity of a broad range of parameters related to grid deformation challenge the practicality of reaching a "conservative" assessment. The steady state analysis provides a simplified and conservative first-order assessment that allows a focus on the central parameter, flow area reduction.

NRC Comment

3.0 LOCA or SSE+LOCA, Item 7

Appendix E describes how reductions in flow area would be accommodated in ECCS performance analyses.

> **(b) Assuming worst deformation in the hot channel is very restrictive. Why not allow low power peripheral assemblies to address peripheral deformations?**

AREVA:

AREVA agrees that assuming worst deformation in the hot channel is restrictive. However, the methodology in ANP-10337P introduces another key conservatism in that it currently limits [

]

NRC Comment

4.0 Grid Crush Test Protocols, Opening Statement

Appendix D describes irradiation effects on grid crush characteristics. The appendix describes results from both separate-effects mechanical testing results on irradiated Zry-4 and M5 guide tubes and grid crush tests in irradiated grids. The conclusions support the following two test protocols:

[
-
-
]

AREVA:

No comment.

NRC Comment

4.0 Grid Crush Test Protocols, Item 1

Section D1 states, "While this appendix presents specific data to demonstrate these effects on Zircaloy-4 and M5, the method derived in this appendix is applicable to spacer grids fabricated from other Zirconium alloys that demonstrate the same behavior."

> **(a) Need for a limitation and condition for only zirconium alloys which demonstrate same behavior?**

AREVA:

An L&C is not needed because the conditions are already explicitly defined in ANP-10337P. Appendix D of ANP-10337P already describes the behaviors that must be present in zirconium alloys in order for this protocol to be applicable.

NRC Comment

4.0 Grid Crush Test Protocols, Item 2

In Section D.3, the [

]

> (a) The [ ] is different between RXA and SRA material. This appendix provides data for Zry-4 and M5 in the RXA condition. It is not clear that these conclusions, including the test matrix discussed above, is valid for SRA material.

AREVA:

AREVA does not fabricate PWR spacer grids with material in the SRA condition. AREVA's PWR spacer grids are fabricated with material in the RXA condition.

NRC Comment

4.0 Grid Crush Test Protocols, Item 3

In Section D.3, grid crush tests are performed on [

] If part of the base methodology, is it appropriate?

AREVA:

This comment is in reference to material presented on page D-12, of Section D.3 in ANP-10337P. This scaling is part of the base methodology and is also defined on page 6-9 of ANP-10337P.

[

]

[redacted]

Errata and Clarifications

Errata and Clarifications

Errata and Clarifications

[redacted]

Errata and Clarifications

[redacted]

Errata and Clarifications

Errata and Clarifications

[redacted]

Source Reference Files for Review

Files for Review

Data Needs for Future Review

(Emphasis on Questions 14 and 41)

Next Steps

Next Steps

- 1st Post-submittal audit – February 8-9, 2017

[ ]