Control Rod Ejection Accident Methodology Pre-submittal Meeting

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Agenda

- Objectives
- Applicable Rod Ejection Accident (REA) regulatory guidance
- PIRT[1] evaluation of REA model requirements
- Method description and models used
- Assessment of codes relative to available benchmarks
- REA uncertainties, biasing, and limiting conditions
- Sample problems
- Summary
- Next steps

[1] PIRT: Phenomenon Identification and Ranking Table

Meeting Objectives

- Present a summary of the REA methodology
- Obtain NRC feedback on the REA methodology
- Develop an understanding of the NRC's planned scope and schedule for revising the associated acceptance criteria
- Discuss the schedule for NRC review and approval of AREVA's REA topical report

Methodology Objectives

- **Address NUREG 0800, Standard Review Plan (SRP) 4.2 Appendix B, "Interim Acceptance Criteria and Guidance for the Reactivity-Initiated Accidents (RIAs)**
- **Applicable to PWR plant and fuel types**
- **Provide opportunity to transition from current legacy REA methodologies**
  - **Requires NRC approval of the following associated topical reports:**
    - ANP-10323P, "Fuel Rod Thermal Mechanical Methodology for BWRs and PWRs," GALILEO™
    - ANP-10297P Supplement, "The ARCADIA® Reactor Analysis System for PWRs Methodology Description and Benchmarking Results"

Planned Schedule

- Pre-submittal tactical meeting – today
- Pre-submittal meeting – 3rd Quarter 2015
- Topical submittal to NRC – September 2015
- Post-submittal meeting – 4th Quarter 2015
- Additional meetings/technical audits, as needed
- Requested NRC approval – 4th Quarter 2017

PWR Control Rod Ejection Accident Methodology

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PWR Regulatory Guidance Sources

- **NUREG 0800, SRP 4.2 Appendix B, Revision 3**
- **Proposed Revision RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors"**
- **Proposed RIA criteria**
  - **Status Report: 50.46c Rulemaking and RIA Guidance, AREVA/NRC Fuel Performance Meeting, Paul M. Clifford, May 2014.**

PWR Regulatory Guidance

	SRP 4.2 App. B Revision 3	NRC's Proposed Change	Estimated Impact of Proposed Change
Failure Criteria	Enthalpy rise limit (Δcal/g) for PWRs is based on relative oxide to clad thickness	Enthalpy rise limit (Δcal/g) based on excess hydrogen for both PWRs and BWRs	Improves M5 limits with burnup About the same for Zr
	High temperature failure limit: For initial powers ≤ 5% 170 cal/g 150 cal/g for pins above system pressure For initial powers > 5% Failure presumed if SAFDL DNBR is reached.	Melting <10% of pellet High temperature failure limit: For initial powers ≤ 5% Limit = 170-(DP-1)*20 Where DP is differential pressure and must include transient fission gas release (TFGR) during event For initial powers > 5% Failure presumed if SAFDL DNBR is reached.	May require tracking of pins for Δcal/g, TFGR, and internal pressure. It requires a method to calculate an appropriate limit for each pin for each transient.

- **AREVA plans to address SRP 4.2 App. B Revision 3 to meet the submittal date.**

PWR Regulatory Guidance

	SRP 4.2 App. B Revision 3	NRC's Proposed Change	Estimated Impact of Proposed Change
Coolability	Max 230 cal/g	No change	
	No fuel melting	<10% of near centerline melting is allowed as a failure.	Fuel melt condition near the centerline could be further evaluated.
	Mechanical energy to coolant from failures must be addressed	No change	
	No Loss of Coolable Geometry	No change	
Dose	TFGR = $(0.2286 * \Delta H) - 7.1419$	Draft RG 1.183 More complex, TFGR is isotope and cal/g dependent.	Release increases even for 1 cal/g insertions.

» **For dose sources, AREVA plans to use Draft RG 1.183 to meet the submittal date.**

Start of Proprietary Discussion

Proprietary meeting will begin with next slide

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Planned AREVA Compliance – Fuel Failure

Fuel Failure

- **For core power ≤5%**
  - A limiting pin power history is defined for Plant and fuel pin type. Oxide thickness is calculated with Galileo™. The Δcal/g limit converted from corrosion to burnup.
  - Current SRP 150 cal/g used for all fuel.
- **For core power >5%**
  - Rods below DNBR SAFDL are assumed failed

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Planned AREVA Compliance – Coolability

- **Maximum energy deposition**
  - All fuel will be shown to be less than 230 cal/g.
- **Fuel melt**
- **Address fuel failure mechanical energy generated with respect to reactor pressure boundary, reactor internals, and fuel assembly structural integrity.**
- **No loss of coolable geometry**

Proposed Compliance with other Licensing Criteria

▶ Failures

[ ]

▶ System Pressure

- The maximum RCS pressure during any portion of the REA should be less than the limit established in the safety analysis of record.
- Alternatively, a value that results in stresses that do not exceed the "Service Limit C" as defined in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, if applicable, may be used.

PIRT Evaluation Of REA Model Requirements

- NUREG/CR-6742 is used as the PIRT for REA.
- The PIRT list of parameters and others to be evaluated are shown below:

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* Items added to PIRT list, beyond NUREG/CR-6742.

Method Description and Codes Used

- Methodology designed to support PWR reactor types with sample cases for W, CE and B&W plants
- Core analysis based on steady state and time dependent ARCADIA® Supplement calculations
  - APOLLO2-A – A fine group lattice physics code that provides coarse energy group nuclear related data
  - ARTEMIS™ – A multi energy group nodal simulator code
  - COBRA-FLX™ – Approved core thermal hydraulics code
- System boundary conditions defined by an approved system code
- Time dependent core thermal solution uses an explicit full core pin by pin model.

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AREAM Calculational Tools and Coupling Options

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Associated Topical Reports

- **NRC's approval of the following associated topical reports is needed:**
  - **ANP-10323P, "Fuel Rod Thermal Mechanical Methodology for BWRs and PWRs," GALILEO™**

[ ]

  - **ANP-10297P Supplement, "The ARCADIA® Reactor Analysis System for PWRs Methodology Description and Benchmarking Results"**

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Accident Simulation Boundary Conditions

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Code Validation from ARCADIA® Supplement

- **Measured Comparisons**
  - Dropped rod transients
  - Ejected rod worth measurements
  - SPERT Measurements
- **Analytical Comparisons**
  - NEA-CRP rod ejection

Method Biasing and Limiting Conditions

- **Define the parameters and the range of applicability as an uncertainty and/or a limiting amount based on allowed or expected variability.**
  - Uncertainty – 15% ejected rod worth uncertainty
  - Allowance – Technical Specifications allow +/- °F on initial condition
  - Expected- Variability based on calculations (e.g., gap conductance)
- **Categorization of the parameters relative to their variability and their impact on the results determines the manner in which the parameter is treated.**
  - Parameters will be tested in a sensitivity analysis.
  - Important parameters will be either biased or results penalized by their variation.

Sample Problems

- Method encompasses specific plant and fuel models and the application to other PWR plant and fuel types will be defined.
- Sensitivities run at HZP, HFP, BOC, and EOC to categorize the parameters and define the biases and penalties.

Sample Problems (cont'd)

- Several power levels and times in life will be calculated with the biased parameters and the penalties defined by the sensitivity analysis.

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Examples

- The provided examples are to illustrate the type of results that will be presented in the topical report.
- The values are provided only for illustration purposes.

Example Presentations of Results for an REA at HZP

Example Presentation of Results

Example Presentation of Results

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At Power Examples

- Similar time dependent figures to HZP will be provided.
- Figures will present the proximity to DNBR SAFDL and coolability criteria.

Example Presentations of Results for an REA at HFP

Coolability

Failures

- **If a pin has been assumed failed because it exceeded the DNBR SAFDL, the following process is used to count the failures.**

Maximum Pressure Calculations

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Cycle to Cycle Validation and Application to Other Plant Types

- The peak in the core may not be the limiting location since the limits are burnup dependent.
  - Enthalpy rise
  - Fuel Melt
  - Coolability – [ ]
- Plant and cycle variations may change the peaking to burnup relationships.
- The topical will present how the calculations will be performed for new contracts (plants different than those presented) and the follow-on cycle verification.

Summary

- AREVA presented an overview of the control rod ejection accident methodology.
- AREVA described the RIA criteria to be addressed/used for the methodology.
  - For fuel failure criteria and coolability, AREVA plans to address SRP 4.2 Appendix. B, Revision 3
  - For dose sources, AREVA plans to use Draft RG 1.183
- AREVA informed NRC staff of:
  - the associated topical reports needing NRC approval
  - The method and models used,
  - Assessment of codes relative to available benchmarks
  - Uncertainties, biasing, and limiting conditions and
  - Planned scope of sample problems
- Additional NRC feedback?

Next Steps

- Pre-submittal meeting – 3rd Quarter 2015
- Topical report submittal to NRC – September 2015
- Post-submittal meeting – 4th Quarter 2015
- Additional meetings/technical audits as needed
- Requested NRC approval – 4th Quarter 2017

Acronyms/Nomenclature

- ASME American Society of Mechanical Engineers
- B&W Babcock and Wilcox
- BOC Beginning of Cycle
- BWR Boiling Water Reactor
- CE Combustion Engineering
- EOC End of Cycle
- HFP Hot Full Power
- HZP Hot Zero Power
- DNBR Departure from Nucleate Boiling Ratio
- LAR License Amendment Request
- LOCA Loss of Coolant Accident
- MDNBR Minimum Departure from Nucleate Boiling Ratio
- PIRT Phenomenon Identification and Ranking Table
- PWR Pressurized Water Reactor
- REA Rod Ejection Accident
- RIA Reactivity-Initiated Accident
- SAFDL Specified Acceptable Fuel Design Limits
- SRP Standard Review Plan
- TFGR Transient Fission Gas Release
- TS Technical Specifications
- W Westinghouse