Burnup Credit and Soluble Boron Credit

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Agenda

- Purpose
- Regulatory Requirements for Part 72 and Part 71
- Guidance for Part 72 and Part 71
- Methods Employed in Part 72 and Part 71 Licensing Calculations
- PWR: Soluble Boron Credit Methodology
- PWR: Burnup Credit Methodology
- Current Challenges in Burnup Credit
- Combining Regulatory Requirements PWR and BWR Spent Fuel

Purpose

- To review the current regulatory requirements, guidance and current practices on criticality analysis for Storage and Transportation
- To develop an understanding of the methods for performing these analyses
- Present perspective on combining regulations for Storage and Transportation

Regulatory Requirements for Part 72

- **72.124: Criteria for nuclear criticality safety**
  - (a) ***Design for criticality safety:***
  - *(b)* ***Methods of criticality control:***
  - (c) ***Criticality Monitoring***
- **72.236: Specific requirements for spent fuel storage cask approval and fabrication**

Regulatory Requirements for Part 71

- **71.55: General requirements for fissile material packages.**
  - ***(b) subcritical with water in-leakage***
  - ***(d) subcritical under the tests specified in 71.71 (NCT)***
  - ***(e) subcritical under the tests specified in 71.73 (HAC)***
- **71.59: Standards for arrays of fissile material packages.**

Guidance for Part 72 and Part 71

- Regulatory Guidance Documents on Criticality
  - NUREG-1536, Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility (Part 72)
  - NUREG-1567, Standard Review Plan for Spent Fuel Dry Storage Facilities (Part 72)
  - NUREG-1617, Standard Review Plan for Transportation Packages for Spent Nuclear Fuel (Part 71)
- Generally provide good understanding of
  - Staff expectations
  - Clarifications on specific regulatory requirements

Guidance for Part 72 and Part 71

- Some of these specific items include:
  - Definition of sub-criticality – maximum k_{eff}, including all applicable biases and uncertainties, is less than or equal to 0.95 on a 95/95 basis,
  - Flooding in the cavity to maximize reactivity, including flooding in the pellet-clad gap,
  - Fresh fuel analysis methodology with generally no credit for integral or removable burnable absorbers unless sufficient justification is provided,
  - Soluble boron credit for loading and unloading operations require operational controls (Part 72), and
  - PWR Actinide-only burnup credit allowance per ISG-8, Rev. 2.

Methods Employed in the Part 72 and Part 71 Safety Analysis

- **BWR Safety Analyses**
  - Fresh Fuel Assumption
  - Flooding with un-borated water
  - No credit for burnable absorbers
- **PWR Safety Analyses**
  - Fresh Fuel Assumption
  - Burnup Credit
  - Soluble Boron Credit (Part 72 only)
  - No credit for burnable absorbers

PWR: Soluble Boron Credit Methodology

- Soluble boron for PWR systems is relatively simple, well established
- Criticality control using geometry and combination of fixed neutron absorbers and/or soluble boron
- Soluble boron and fixed poison requirements are typically optimized based on basket capacity, spent fuel loading (enrichment) and plant operational considerations
- Technical Specifications require verification of boron concentration of the water in the Cask Cavity

PWR: Burnup Credit Methodology (1 of 2)

- Burnup Credit refers to taking "credit" for the reduction in the reactivity due to fuel assembly irradiation
  - Negative reactivity associated with fuel assembly irradiation is sufficient to offset the soluble boron credit
  - Licensing calculations are exhaustive and require extensive validation
  - Major portions of these licensed analyses are proprietary
- Credit can be taken for Actinides and/or Fission Products depending on the group of isotopes that are included in the evaluation

PWR: Burnup Credit Methodology (2 of 2)

- **Burnup credit methodology consists of Depletion, Criticality and Implementation**
  - **ISG 8, Rev. 2 provides the staff guidance on actinide-only burnup credit**
  - **Currently, fission-product burnup credit is subject to review and approval on a case-by-case basis**
  - **ANS Standards Committee / Working Group on burnup credit has established the ANS 8.27 standards and a revision to the standard is in progress**

Depletion Analysis Methodology

- Establish the concentrations of the various isotopes as a function of burnup, enrichment and cooling time
- Requires benchmarks and sensitivity calculations to quantify biases and uncertainties
- Both 1-D and 2-D depletion codes are employed
- Trend Analysis is necessary

Criticality Analysis Methodology

- Determine the burnup loading curves
- 3D models are typically used
- Fuel composition from results of depletion analysis
- Effect of axial and horizontal burnup variations
- Requires benchmarks and sensitivity calculations to quantify biases and uncertainties associated with burnup credit
- Integral benchmark methods are those that combine the effect of depletion and criticality benchmarking are available

Burnup Credit Methodology References

Depletion Analysis Methodology References

- NUREG/CR-6700
- NUREG/CR-6759
- NUREG/CR-6760
- NUREG/CR-6761
- NUREG/CR-6798
- NUREG/CR-6811
- NUREG/CR-7012
- NUREG/CR-7013
- ORNL/TM-12973
- ORNL/TM-13317

Criticality Analysis Methodology References

- NUREG/CR-5661
- NUREG/CR-6361
- NUREG/CR-6800
- NUREG/CR-6801
- NUREG/CR-6951
- NUREG/CR-6969
- NUREG/CR-6979

Current Challenges in Burnup Credit

- Burnup credit methodology is still evolving
- Most of the analyses are vendor proprietary although some of the elements are public
- Additional guidance on burnup credit would
  - Reduce the complexity
  - Improve efficiency in review and approval of license applications

Combining Regulatory Requirements PWR Spent Fuel

- Several key elements of the criticality analyses can be combined into a single licensing basis calculation for review and approval for storage and transportation
- "Full" burnup credit (actinides and fission products) will be required to meet requirements for both regulations
- Transportation of high burnup fuel – criticality considerations may also require undamaged fuel assumptions or additional credit for higher burnups
- Loading curves to meet Part 71 criteria that require higher cooling times could potentially be limiting for their storage

Combining Regulatory Requirements BWR Spent Fuel

- Current storage analyses are also performed using fresh fuel with fresh water moderation – therefore, no additional transportation considerations are needed
- Transportation of high burnup fuel – criticality considerations may also require undamaged fuel assumptions to meet regulatory requirements for BWR fuel.
- Consideration of burnable absorber credit or burnup credit

Comments / Questions

- What ?
- How ?
- Is this it ?

AREVA