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 $k_{\text{eff}}$, 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
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.
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
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
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?