



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 ?**