Criticality Analysis for NMP1 Boraflex Racks: No Boraflex Credit, 3 out of 4 Loading, and Cell Blockers

November 6, 2017

Pre-Submittal Briefing

Exelon Generation®

Introduction

- **NMP1 Spent Fuel Pool (SFP)**
  - ➢ 2 Boraflex Racks + 14 Boral Racks
- **What's the Problem?**
  - ➢ Concerns of Boraflex degradation: proactively and conservatively address
- **What to Do?**
  - ➢ Perform a new criticality analysis for the 2 Boraflex racks
    - o No credit is taken for the residual Boraflex
  - ➢ 3 out of 4 loading pattern is used to reduce reactivity
    - o Permanent Cell Blockers will be installed in accordance with NEI 12-16
  - ➢ No changes were made on the Boral racks
  - ➢ Revision to Technical Specifications (TS) 5.5 will be made on non-poison flux trap racks and Boraflex racks to reflect the current pool configuration and description in the current UFSAR.

Exelon Generation®

New Criticality Analysis Overview

- **Consistent with the Peak Reactivity Methodology Previously Approved**
  - Quad Cities: ML14346A306/ML16231A131
  - Dresden: ML15343A126

- **In Compliance with Current Industry Guidance/Standards**
  - 10 CFR 50 Section 68 and Appendix A
  - Kopp Memorandum
  - DSS-ISG-2010-01
  - NEI 12-16

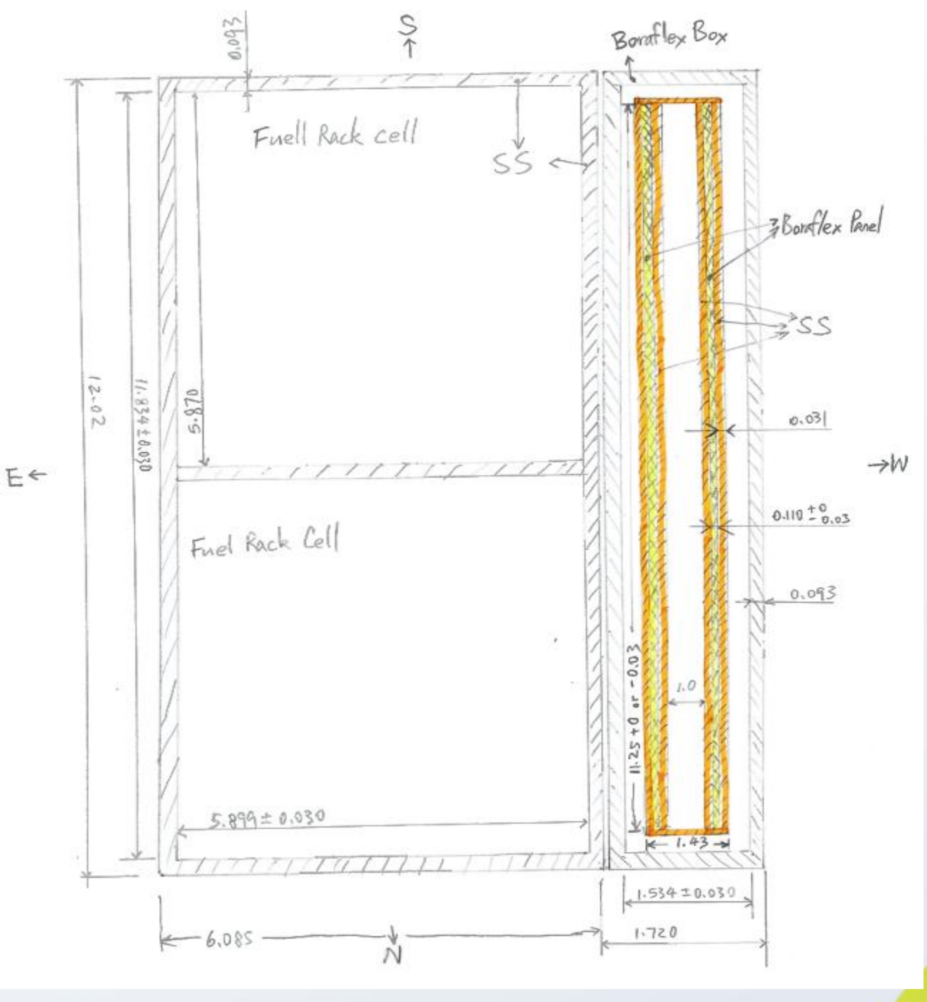
- **Computer Codes: CASMO & MCNP5-1.51**

New Criticality Analysis Overview (Cont'd)

- **Analysis Results Summary**
  - Permanent cell blockers will be installed in specific locations in Boraflex racks
    - Maintains a sufficiently low reactivity area along interface with Boral racks
    - Precludes the need to leave an entire empty row along the interface with Boral racks
  - Misload accident is precluded
    - Peak reactivity lattice is used
    - The empty cells are blocked with cell blockers
  - Final K-eff
    - 0.9390: all normal/accident conditions and uncertainties and biases
    - Margin to regulatory limit of 0.011
    - Includes an additional "Administrative margin" of 0.01 (biases) in SCCG value
    - Supports application of current TS limits for Boral Racks to Boraflex racks
      - Achieves commonality and consistency between Boral and Boraflex racks

Criticality Safety Analysis Specifics

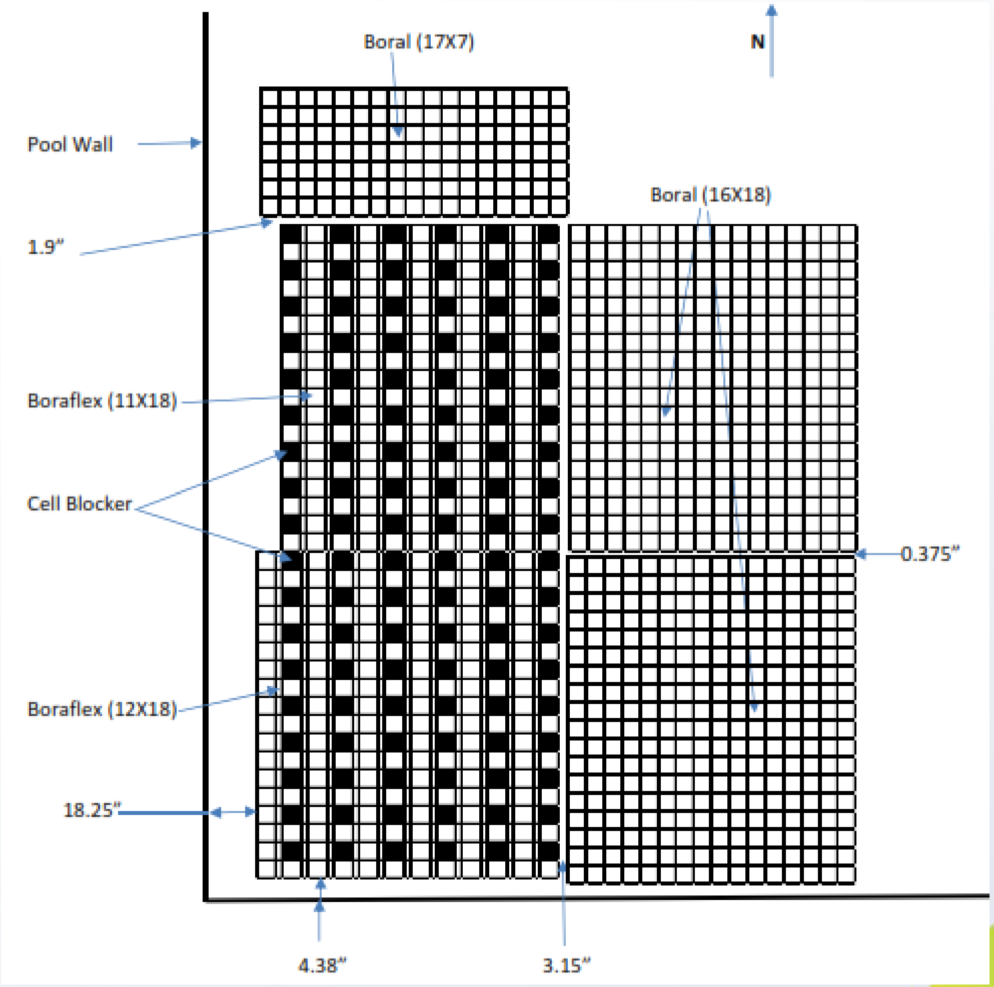
- Boraflex Storage Rack Design



Exelon Generation.

Criticality Safety Analysis Specifics (Cont'd)

- SW Corner Storage Rack Configuration in SFP



Exelon Generation.

Criticality Safety Analysis Specifics (Cont'd)

- No poison so maximum temperature is used (100 C, also bounds accident condition)
- Cell blockers are not modeled explicitly; steel is an absorber.
- Eccentric positioning and channel inclusion treated as a bias (bounding case is no channel, all eccentric to rack center; bias = 0.0182)
- Peak reactivity isotopic compositions from CASMO depletion calculations considering bounding Core Operating Parameters (COP)
- All reactivity calculations for K-eff determination are performed using MCNP5-1.51
- Accident conditions evaluated: Dropped bundle outside the racks, rack movement, pool temperature.

Criticality Safety Analysis Specific Results

- All actual as-built NMP1 fuel bundle lattices evaluated.
- Most reactive as-built actual lattice studies show that the negative reactivity introduced by the cell blockers > 0.11 delta-k
- Maximum K-calc for as-built lattices in the Boraflex racks with cell blockers is ~ 0.82

Exelon Generation.

Interface Evaluation

- **Boraflex Racks**
  - ➢ Located in the SW corner and adjacent to 14 Boral racks along the east and north
  - ➢ Old flux trap style design: Flux traps (1.72”) are parallel to N-S
  - ➢ The geometry of the Boraflex racks with cell blockers creates a low reactivity configuration (Max K-calc=0.82 for as-built lattices).
- **Boral Racks**
  - ➢ Boral neutron absorber panels on the outside of the Boral racks along the interface significantly reduce reactivity in the interface area.
- **Interface gaps**
  - ➢ East interface gap is 3.15” and north interface gap is 1.9”. Both gaps are larger than the Flux traps in Boraflex racks and hence further reduce the reactivity in the interface area.

Exelon Generation.

Interface Evaluation (Cont'd)

- **Cell to Cell Pitch**
  - Both racks are nearly identical for the N-S cell pitches.
  - E-W cell pitches are 7.805" for Boraflex and 6.06" for Boral racks.
  - Therefore, the racks on one side of the interface can be assumed to be a continuation of the rack on the other side of the interface.
- **Max SFP temperature used, which yields 0.0144 delta-k over Min SFP temperature**
- **The bounding reactivity of the Boraflex rack used to show compliance with the regulatory requirements is K-calc = 0.8697**
- **Interface Evaluation Conclusion:**
  - The interface between the Boraflex and Boral racks in the SFP is an area of low importance (i.e., low reactivity) and no further evaluations are required.

TS Evaluation

- The Boral rack TS requires that all fuel lattices have a maximum enrichment of 4.6% U-235 and a SCCG ≤ 1.31.
- Will apply Boral racks TS to Boraflex racks.
- Super lattices were created from the existing most reactive as-built lattices to bound the above TS requirements.
  - ➢ Enrichment of each pin was increased to 4.6% U-235 and Gd rod loading was varied until the super lattice SCCG was slightly above 1.31
  - ➢ Each super lattice has a unique Gd loading that yields a SCCG of at least 1.31
- Design Basis Lattice
  - ➢ The most reactive lattice (peak reactivity in the Boraflex rack) of all super lattices
  - ➢ Used to perform the analysis calculations to show compliance with regulatory requirements (i.e., determination of Total Correction Factor (TCF))

Final Analysis Results

- Bias & Unc
  - 0.0693
- Normal K_{eff}
  - 0.9370
- Accident K_{eff}
  - 0.9390
- Gray Boxes
  - proprietary

Analysis Uncertainties	
BWR fuel eccentric positioning bias uncertainty (Appendix B, Table B.9)	
BWR fuel rotation bias uncertainty (Appendix B, Table B.10)	
BWR fuel tolerances (Appendix B, Table 11)	
BORAFLEXTM rack manufacturing tolerances (Appendix B, Table 12)	
Depletion related geometry changes bias uncertainty (Appendix B, Table 13)	
Depletion uncertainty (Appendix B, Table 14)	
Cooling time bias uncertainty (Appendix B, Table B.15)	
MCNP code bias uncertainty (Table 2.2)	
MCNP calculation uncertainty (2 sigma)	
statistical combination of analysis uncertainties	0.0154
Analysis Biases	
BWR fuel eccentric positioning bias (Appendix B, Table B.9)	
BWR fuel rotation bias (Appendix B, Table B.10)	
Depletion related geometry changes bias (Appendix B, Table 13)	
Cooling time bias (Appendix B, Table B.15)	
MCNP code bias (Table 2.3)	
Administrative bias (Section 2.3.8)	
SCCG bias (Section 7.8)	
Sum of biases	0.0539
Total correction factor	0.0693
Maximum k_{calc} for normal conditions	0.8677
Maximum k_{eff} for normal conditions	0.9370
Maximum k_{calc} for accident conditions	0.8697
Maximum k_{eff} for accident conditions	0.9390
Margin to Regulatory Limit	0.0110

Exelon Generation

Conclusions

- **Meet 10 CFR 50.68 (b)(4) requirement:**
  - ➢ The effective neutron multiplication factor (Keff) is less than or equal to 0.95 for all normal and accident conditions with 95% probability at a 95% confidence level.

- **Supports application of current TS limits for Boral Racks to Boraflex racks**
  - ➢ Lattice initial maximum planar average enrichment (MPAE) ≤ 4.6 wt% U-235
  - ➢ Lattice standard cold core geometry (SCCG) $K_{inf} \leq 1.31$

- **Questions and Comments**
  - ➢ Thanks

Exelon Generation®