More Realistic Analysis of Spent Fuel Pool Accident Progression

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Spent Fuel Pool - Background

- Constructed of thick, reinforced concrete walls with stainless steel liner
- Fuel in the spent fuel pool generates small fraction of the heat in the reactor
  - Fuel in spent fuel pool which is relatively full (e.g., containing 4 reactor cores) generates heat at a rate which is 10 to 40 times lower than that of fuel in reactor when reactor is shutdown
  - Lower heat generating capacity of spent fuel means heat removal is simple, even under adverse conditions

Spent Fuel Pool Studies

- Past NRC studies of spent fuel pools used conservative models and assumptions to evaluate potential for fuel heatup, fission product release, and offsite consequences
  - Bounding pool conditions
    - Fuel burnup at licensing limit (60 GWd/t)
  - Simplified, conservative models for fuel heatup
    - No heat transfer between higher-power and lower-power fuel
  - Assumed conservative fission product release timing and magnitude with limited or no credit for fission product release deposition in building

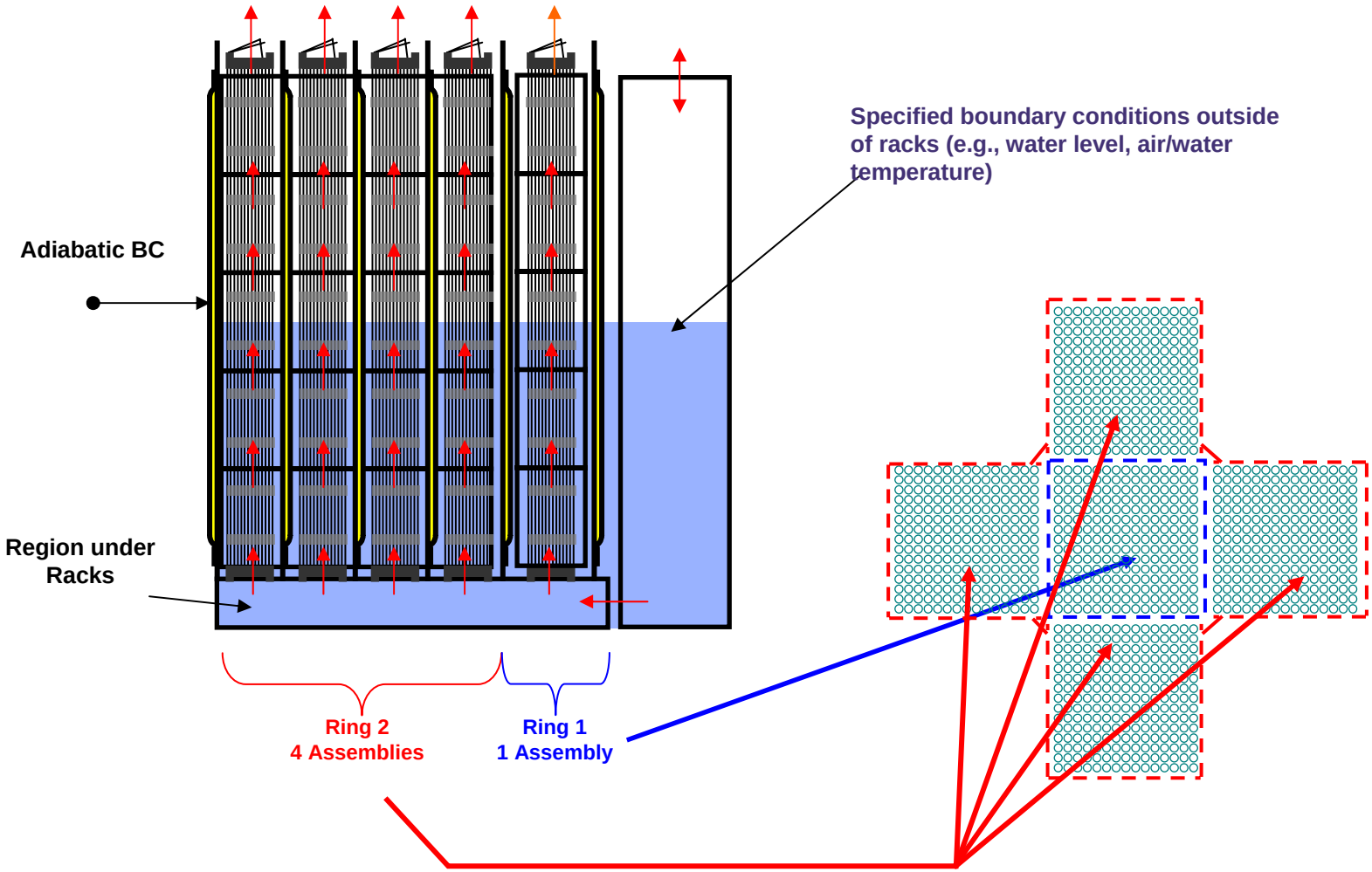
More Realistic SFP Analysis

- Past work primarily limited to “early phase” heat-up calculations, no integrated severe accident analysis performed
- Most codes only analyzed potential for zirconium fire using “ignition temperature” criteria
  - No severe accident phenomenological models
  - Modeling limitations of historical tools
    - Damage propagation
    - Oxidant depletion
    - FP release and transport modeling
    - Heat transfer modeling
    - Flow mixing
- Past shortcomings now overcome with state-of-the-art severe accident modeling

Modeling Approach

- Applied MELCOR code
  - 2 Model Approach - Separate Effects and Whole Pool/Building Models
- Separate Effects Model
  - Developed first to guide whole pool model development
  - Accurately represents single assembly geometry and 4 neighbors
  - Fast running
  - Controlled boundary conditions
  - Identify sensitivities and uncertainties
- Whole Pool/Building Model
  - Integral effects
  - Whole pool source term

Separate Effects SFP Model



Separate Effects SFP Model

- **Results**
  - **Heatup limited by heat transfer to lower decay power assemblies**
  - **Heatup is also limited by steam cooling**
- **Performed sensitivity studies to better understand integrated severe accident behavior**
  - **Decay power**
  - **Initial oxide layer**
  - **Flow resistance**

Whole Pool/Building Model

- **Results**
  - **Draindown time can be long**
  - **Heatup limited by heat transfer to lower decay power assemblies**
  - **Heatup slowed by enhanced convection due to open areas in the pool, such as empty racks**

Supporting Tests and Analyses

- Cladding oxidation tests
  - Updated correlations for oxidation in air
- Fuel assembly heatup and propagation tests
  - Updated assembly flow resistance
  - Pre- and post-test calculations with MELCOR confirm its thermal hydraulic modeling
- Heat transfer between fuel assemblies
  - COBRA-SFS model used to confirm MELCOR predictions of radiative heat transfer for separate effects model
  - MELCOR modified to explicitly model spent fuel rack
- Flows in pool and surrounding building
  - CFD models used to characterize flow patterns to guide MELCOR nodalization

Conclusion

- Application of integral severe accident modeling (MELCOR) demonstrates
  - fuel in the spent fuel pool is much more easily cooled than predicted in earlier studies
  - even if cooling is lost, more time is available to restore cooling and prevent fuel damage
  - even if fuel is damaged, consequences will be reduced from past studies
- Application of MELCOR to drained spent fuel pool validated by benchmarking against full-scale fuel assembly tests at SNL
- MELCOR analyses used to identify and assess options for enhancing the coolability of spent fuel in pool storage