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U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Spent Fuel and Waste Science and Technology (SFWST)

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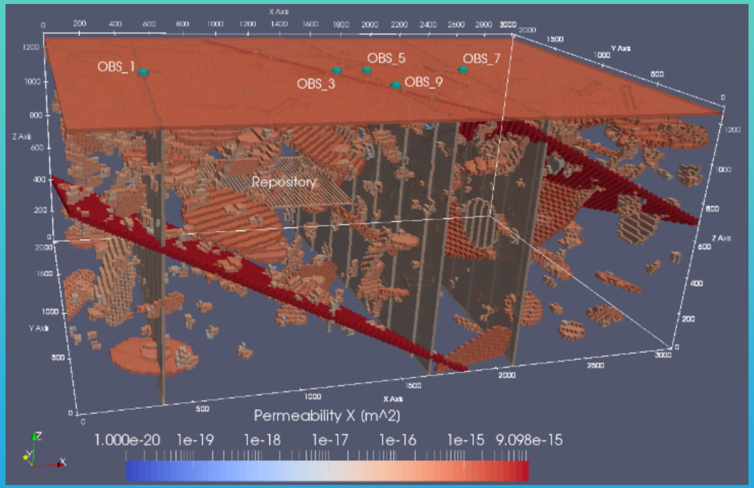

International Approaches to Postclosure Criticality Safety – United States

American Nuclear Society
NCSD Panel
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To the extent discussions or recommendations in this presentation conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this presentation in no manner supersedes, overrides, or amends the Standard Contract.

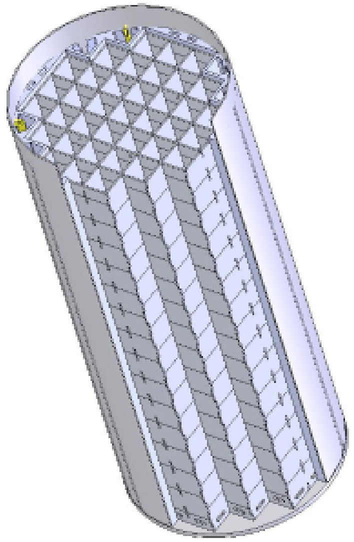
This presentation reflects technical work which could support future decision making by DOE. No inferences should be drawn from this presentation regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

Legal Framework and Regulatory Context

- The set of postclosure performance requirements that would apply to a future repository is somewhat unclear
  - The postclosure performance regulations that applied to the proposed Yucca Mountain repository (10 CFR 63 (NRC) and 40 CFR 197 (EPA)) were specific to that repository
  - The postclosure performance regulations that apply to a future geologic repository exist (10 CFR 60 and 40 CFR 191) but are likely to be revised to be risk-informed and performance-based
  - For a future repository, it is assumed that the new requirements that would apply would be similar to those that were applicable to YM
- The regulations do not require that postclosure criticality be prohibited
  - For modeling postclosure performance all features, events, and processes that could affect the disposal system must be identified
  - Features, events, and processes that have less than one chance in 10^8 per year of occurring for 10^4 years can be excluded from the 10^6-year postclosure performance assessment
  - Features, events, and processes with a higher chance of occurring can be excluded from the postclosure performance assessment if the consequences are not significant

US Approach to Postclosure Criticality

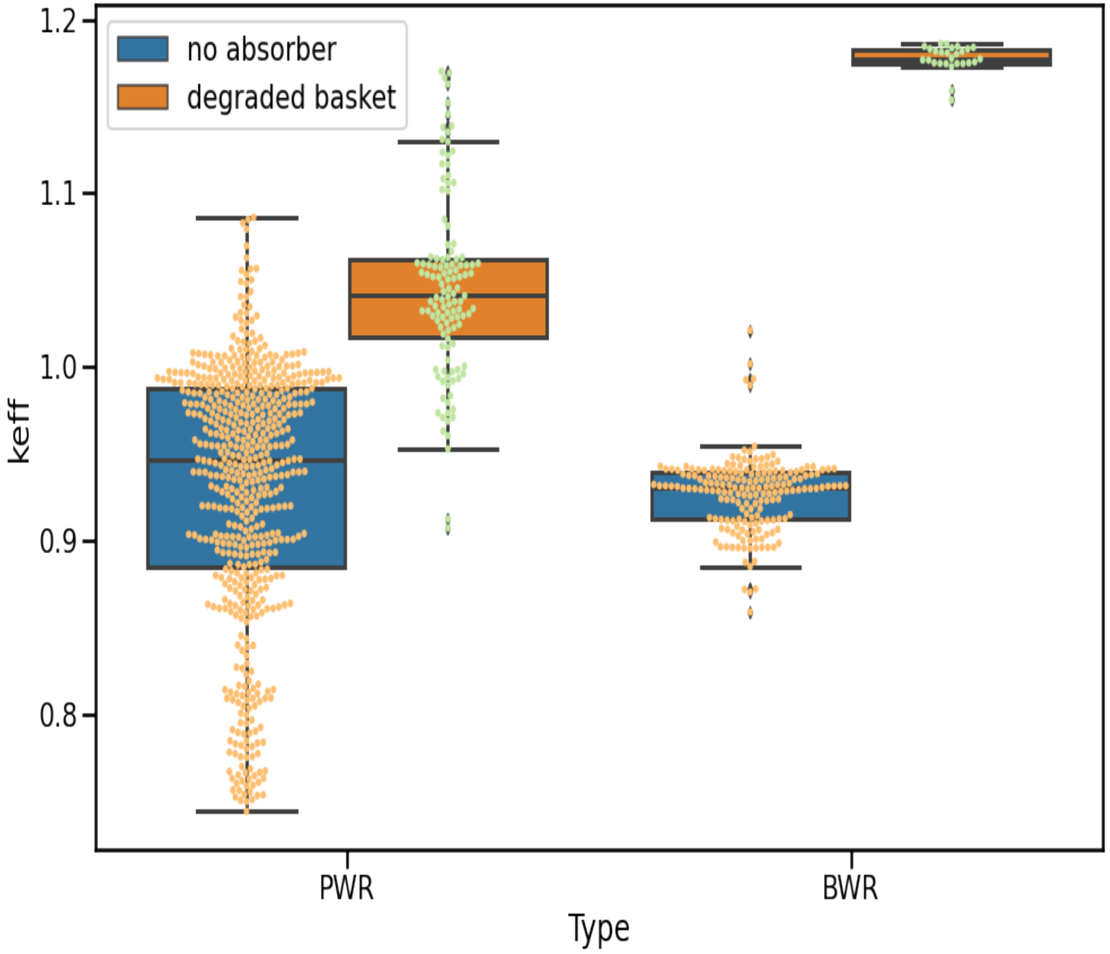
- For Yucca Mountain, postclosure criticality was excluded from the performance assessment calculations on the basis of probability
  - Disposal canisters used borated stainless steel absorber plates as neutron absorbers
  - Neutron absorbers were thick enough to prevent criticality for 10^4 years after closure
- The license application for Yucca Mountain was suspended; disposal canisters were not manufactured and, thus, not used for dry storage of spent nuclear fuel (SNF)
- Majority of the SNF is being stored in dual-purpose (storage and transportation) canisters (DPCs)
  - DPCs are not designed or loaded with disposal considerations
  - DOE can either repackage SNF for disposal OR
  - DOE can avoid repackaging the SNF currently in thousands of welded-shut DPCs by disposing of the canisters directly



MPC-37 canister (from Greene et al. 2013)

DOE is investigating feasibility of direct disposal of DPCs

- DOE investigating second option; direct disposal of DPCs
  - Identified heat generation, engineering, and postclosure criticality as technical issues
- Using stylized degradation scenarios and including burn-up credit, determined that some percentage of as-loaded DPCs would not remain subcritical after failure
- US multi-faceted investigation includes
  - Higher fidelity modeling to identify DPCs with criticality probability
  - Preconditioning of DPCs to reduce probability of criticality in a repository
  - Assessing the consequence of criticality in a repository



US Approach to DPC direct disposal – Reducing Probability of Occurrence

- Adding filler material to existing welded-shut canisters containing SNF
  - Added through original drain or vent ports, or new ports created by drilling
  - Provide moderator exclusion
  - Other desirable properties have been identified
  - Molten metals
  - Resins or cement slurries
- Re-designing neutron absorbing materials and structures in future canisters
  - Inserting disposal control rods
  - Replacing aluminum-based neutron absorbers with materials that are more corrosion-resistant
  - Loading SNF in a configuration optimized to minimize reactivity

US Approach to to DPC direct disposal – Assessing Consequences

- Identify features, events, and processes that could affect postclosure criticality, those that could be affected by it, or both
- Develop the tools needed to include the relevant features, events, and processes in postclosure performance models
- Model the occurrence of two “types” of postclosure criticality
  - Steady-state criticality
    - Constant power, timescale of thousands of years
    - Major effects: Inventory change, thermal effects on natural and engineered barrier performance
  - Transient criticality
    - Variable energy, timescale of seconds
    - Major effects: inventory change, mechanical effects on natural and engineered barriers
- Compare repository performance with and without postclosure criticality in two types of repositories
  - Hypothetical saturated repository in clay
  - Hypothetical unsaturated repository in alluvium

Current Status of Investigations

- Tin was successfully cast on a mock-up model
  - No large voids, materials are compatible
  - Computational fluid dynamics model developed and validated
- Work on cement fillers focused on three different cements
  - Want to optimize the composition to achieve dense and well consolidated samples
  - Aluminum phosphate and calcium aluminate phosphate cements show the most promise
- Focusing on zone loading, as it does not require re-licensing canisters
- Preliminary results for steady-state criticality in hypothetical saturated shale repository: no difference in repository performance
- Preliminary results for steady-state criticality in hypothetical unsaturated alluvial repository: low power for short periods of time => limited change in inventory and thermal effects on engineered and natural barriers
- Transient criticality modeling: characterized power pulse for both repository environments, working on translating that to mechanical effects

Benefits of Cooperation with IGD-TP

- Compare approaches to postclosure criticality
  - Worst-case assumptions vs. “average conditions” assumptions
  - Use of burn-up credit to assess reactivity
- Compare approach to technical issues
  - Coupling in-package criticality models and drift-scale thermohydraulic models
  - Determining mechanical effects of transient criticality