# *Criticality Modeling for Safe Disposal of Spent Nuclear Fuel*

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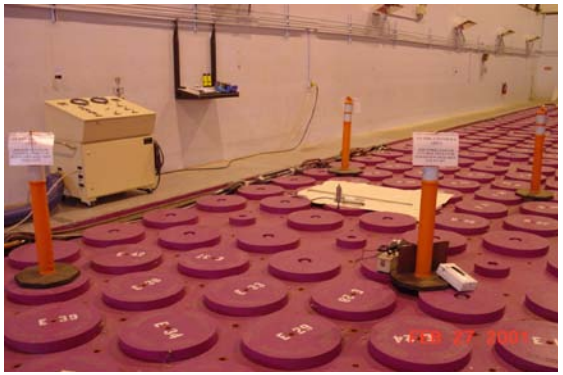

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# Outline

- DOE's inventory
- Interim Management
- Fuel data, QA, NDA, and performance allocation
- Packaging strategy
- Criticality approach for SNF in Yucca Mountain license application
- Benchmark experiments
- Lessons learned
- Waste disposal challenges
- Summary

# DOE's Inventory

- SNF
  - ~2500 MTHM, highly diverse
  - Much is fully enriched, low burnup, some with significant amounts of plutonium
  - Fast reactor, and some thorium-based fuels contain very high specific fissile concentrations
  - Some thermal reactor fuels are self-moderating
  - Fuel conditions range from intact to fully degraded
- HLW
  - Mostly a monolithic waste form; borosilicate glass
  - Calcine, a metal oxide free flowing solid, exists at Idaho. Disposition options are being investigated.
  - HLW does not present significant criticality issues

# Interim Management

- Both wet and dry storage systems
  - Wet pools have adequate water chemistry controls to maintain geometry of both fuel and storage environment; DOE does not rely on soluble or fixed neutron absorbers
  - Dry storage systems include both inerted canisters and unsealed canisters vented through filters; DOE does not rely on fixed neutron absorbers
- Criticality analyses use fresh fuel assumptions and traditional methods for criticality safety

# Fuel Data, QA, and NDA

- Some fuel data resources predate modern QA programs
  - Criticality analyses have utilized historical records and very conservative assumptions
- MC&A data is based on end-of-life values
  - It can be used to corroborate BOL assumptions
  - Historically, shipper/receiver values were resolved after reprocessing
- NDA measurements are viewed as confirmatory and are not practicable on highly diverse inventories
  - NDA will not reduce uncertainty in existing data sources even for very old fuel
  - NDA does give insight into fuel burnup

# Packaging Strategy

- Interim Management
  - Fuel would be packaged into standardized canisters based on Yucca Mountain disposal analyses. Nuclear poisons would be added based on current disposal analyses.
  - Nuclear poisons are not required for interim storage or transportation
- Transportation
  - Seek NRC approval for crediting canister leaktightness during transportation. Significantly reduces the fuel-specific analyses (and associated data) needed to demonstrate compliance by crediting the canister boundary for excluding moderators.
- Disposal
  - Relies on both fixed and dispersed nuclear poisons; all fuel is assumed to degrade

# Current Disposal Criticality Analyses

- Both preclosure and postclosure are probabilistically screened out
- Preclosure analyses
  - SNF canister credited for exclusion of moderator based on fragility analyses. Relies heavily on drop test results, modeling, and published material property data.
  - HLW canister is assumed to breach. Criticality safety analysis based on single parameter fissile concentration limit from ANS 8.1
- Post closure analysis
  - SNF is assumed to fully degrade. Both fixed and dispersible nuclear poisons are credited.
  - HLW criticality safety analysis based on specific glass composition provided by DOE

# Lessons Learned

- Conservatism in the postclosure criticality analyses resulted in the requirement of neutron absorbers
- Conservatisms were driven by:
  - Regulatory period
  - Evolving waste package designs
  - Evolving model abstractions (early WP failures, seismic, igneous)
  - SNF characterization
- A more aggressive burnup credit data collection program for CSNF should have been pursued much earlier in the process when funding was abundant.
- A consequence-based approach could have supplemented the current probabilistic approach and mitigated concerns regarding assembly and neutron absorber misloads, burnup credit, and administrative margin

# *Waste Disposal Challenges (R&D needs)*

- Direct disposal of DPCs
  - Different absorbers from LA design; several billion dollars at stake
- High cost of neutron absorbers
  - Commercial SNF with powder metallurgy BSS, DOE SNF with Ni-Gd, several billion dollars at stake
- Neutron absorbing shot is still a conceptual solution
  - Form of absorber and base shot have not been finalized yet
- Neutron absorber misload issues
  - Methods for confirming the presence of absorbers have not been developed
- The ever-evolving plutonium disposition form
  - An analysis requires a final approach and characterization data

# Summary

- Degraded criticality analyses for some DOE fuels have been extremely challenging
- DOE's baseline is to package SNF and HLW per Yucca Mountain design analyses
  - Disposal criticality constraints will likely meet disposal requirements in other geologic settings
- Conservatism in disposal assumptions continues to drive technology needs
- NDA technology not appropriate for the diverse variety of DOE fuels

Thank you very much for the invitation to join you today, and for your kind attention.

I will be glad to take some questions.

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