SAND2015-6632PE

Used Fuel Disposition Campaign

Technical Feasibility of Direct Disposal of DPCs – Summary and Recommendations

Laura Price
Sandia National Laboratories

Used Fuel Disposition Working Group Meeting
Las Vegas, NV
June 11, 2015

Outline

- Purpose of the report
- Contributors
- Safety
- Engineering Feasibility
- Thermal Management
- Postclosure Criticality Control
- Recommendations

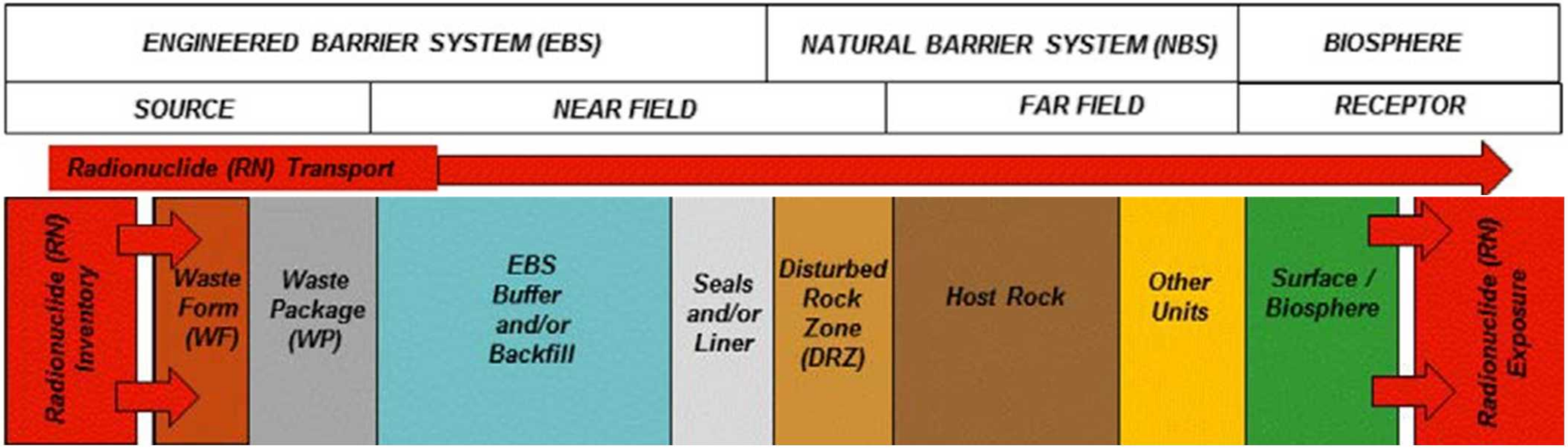
Purpose of the Report

- **Summarize results of a multi-year study of the feasibility of disposing of spent nuclear fuel in dual-purpose canisters**
  - Safety
  - Engineering feasibility
  - Thermal management
  - Postclosure criticality control
- **Recommend further information needs, particularly site-specific information needed to take disposal of SNF in DPCs into account in site screening or siting decisions**
- ***Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters* (FCRD-UFD-2015-000129)**

Contributors

- **Sandia National Laboratories**
  – Ernie Hardin, Elena Kalinina, Teklu Hadgu, Anastasia Ilgen, Charles Bryan, Michael Voegele, Geoff Freeze, and Katrina Groth
- **Los Alamos National Laboratory**
  – Frank Perry
- **Oak Ridge National Laboratory**
  – John Scaglione, Kaushik Banerjee, Justin Clarity, Robert Jubin, Vladimir Sobes, and Rob Howard
- **Savannah River National Laboratory**
  – Joe Carter, Thomas Severynse

Postclosure Safety



Postclosure Safety

- Salt repository concept
  - Postclosure safety relies primarily on backfill and host rock
- Hard-rock, unbackfilled, open concept
  - Postclosure safety relies primarily on waste package
- Hard-rock, backfilled, open concept
  - Postclosure safety relies primarily on waste package
- Sedimentary, backfilled, open concept
  - Postclosure safety relies primarily on host rock
- Cavern-vault disposal concept
  - Postclosure safety relies primarily on backfill/buffer

Engineering Feasibility

- **Disposal Overpacks**
  - Site-specific design, either corrosion-resistant or corrosion-allowance
- **Shielding**
  - Within current state of practice
- **Surface-to-Underground Transportation**
  - Vertical shaft with hoist; hoist with required payload not yet developed
  - Straight ramp with rail-based or rubber-tire based transport vehicle
  - Spiral ramp with rubber-tire based transport vehicle; rubber-tire based vehicle with required payload not yet developed
- **Underground Transportation**
  - Rail-based or rubber-tire based

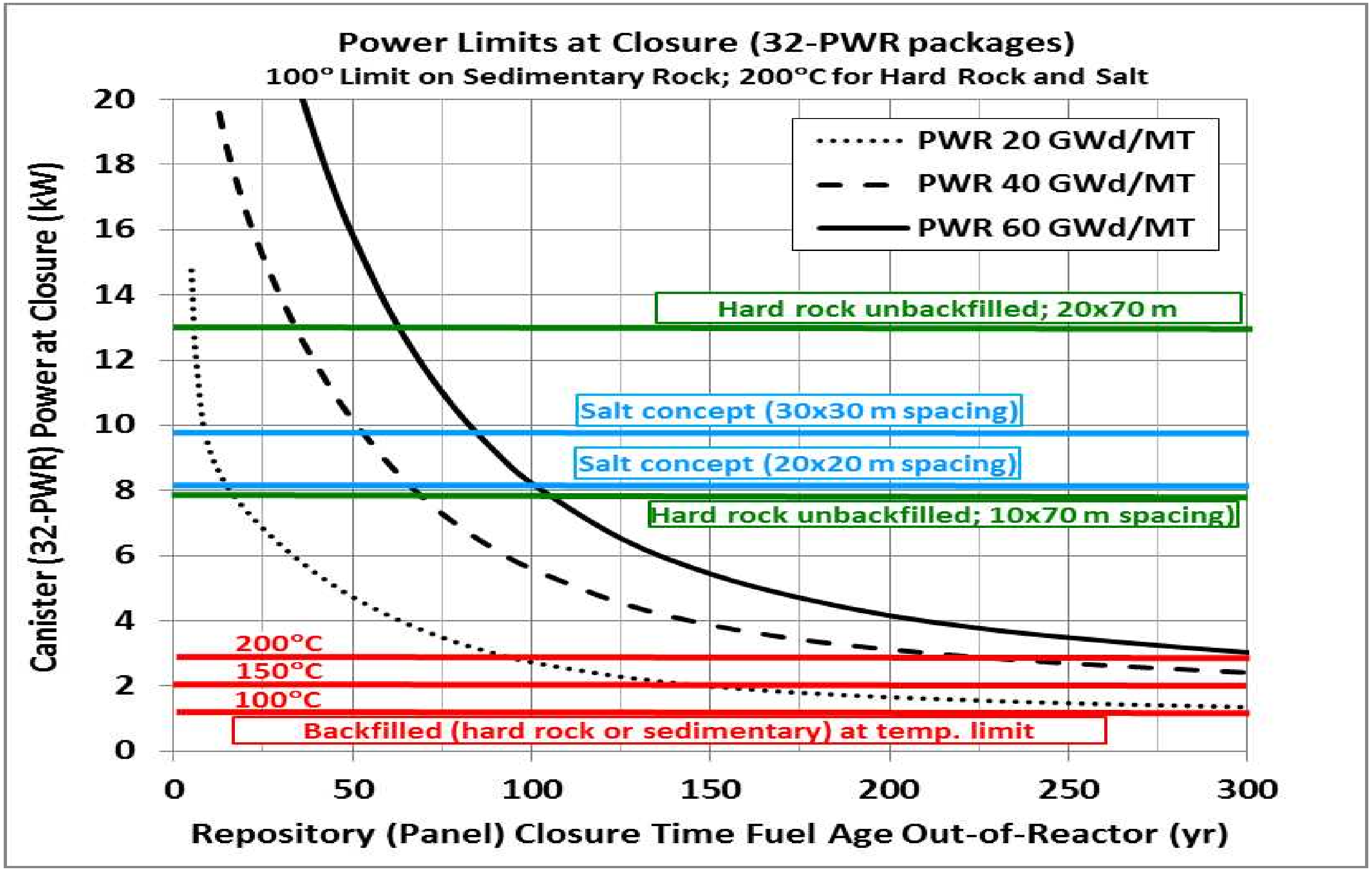
Engineering Feasibility (cont'd)

- **Emplacement Methods**
  - Open or enclosed
- **Buffer and Backfill Materials**
  - Clay-based materials studied extensively; have low thermal conductivity and peak temperature target of 100°C
  - Salt would be used for a salt repository; higher thermal conductivity, peak temperature tolerance of at least 200°C
- **Water Diversion**
  - Drip shield or backfill/buffer
- **Ground Support**
  - Excavation and ground support methods readily available
  - Requiring long-term stability (100 years or more) would involve a more complex system

Thermal Management

- **Peak temperature and time limits used in study**
  - 100°C for clay-based buffer/backfill and clay-rich sedimentary host rock
  - 200°C for crystalline hard rock and salt
  - 350°C for cladding
  - 100 years of above-ground storage for DPCs
  - 50 years of ventilation
- **Enclosed disposal modes not recommended (except for disposal in salt)**
- **Salt disposal concept and hard-rock unbackfilled open disposal concept are the most feasible with respect to thermal management**

Thermal Management



Postclosure Criticality Control

- Neutron-absorber materials will not last over repository time scales
- Criticality is possible ONLY if DPCs are flooded with groundwater
- To be excluded from the postclosure performance assessment on the basis of probability, the probability of criticality must be less than 10^{-4} over 10,000 years (or 10^{-8} per year).
- To be excluded from the postclosure performance assessment on the basis of consequence, the criticality events must have a negligible effect on repository performance objectives.

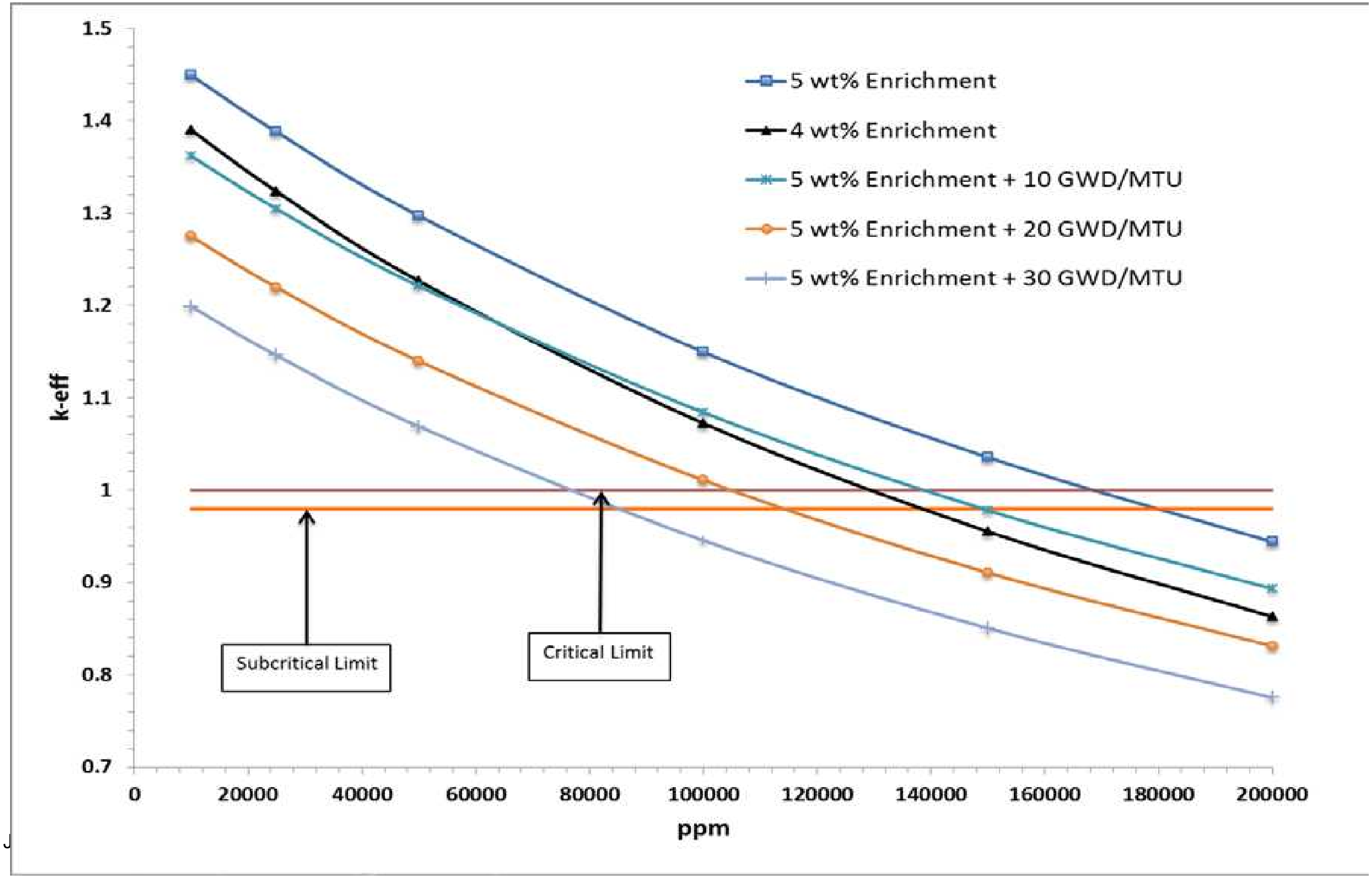
Postclosure Criticality Control – Increasing Overpack Reliability

- **Examined the 2007 DOE estimate of the probability of failure of an overpack from manufacturing defects**
- **Conducted an importance analysis to identify primary drivers of the failure probability**
- **Concluded that no single change to the system would drive the probability of failure below 10^{-8} failures per package**
- **Identified several opportunities for improving the previous modeling approach**
  - Use updated Human Reliability Analysis methods
  - Include a well designed monitoring system to the overpack manufacturing process and take credit for it in the analysis

Postclosure Criticality Control – Degradation Configurations and Effect of Chlorine

- **Developed two stylized configurations representing degraded states**
  - Total loss of neutron absorber from unspecified degradation and transport processes
  - Loss of the internal basket structure (including neutron absorber components) resulting in elimination of assembly-to-assembly spacing.
- **Looked at 17 common dissolved aqueous species in various pore water compositions**
- **Chlorine is the only naturally abundant, neutron-absorbing element in groundwater that can offer significant reactivity reduction**

Postclosure Criticality Control – Effect of Chlorine with Degraded Basket Configuration



Postclosure Criticality Control – Calculations for As-Loaded DPCs

- **Summary of analysis results for eight sites**
  - Seven PWR sites, one BWR site
  - Seven used loss-of-absorber configuration; one used basket-degradation configuration

Number of Canisters	Number of Canisters with K_{eff} > 0.98 (design basis analysis)	Number of Canisters with K_{eff} > 0.98 (as-loaded analysis)	Number of Canisters with K_{eff} > 0.98 if chlorine is present at 19,000 ppm or greater	Number of Canisters with K_{eff} > 0.98 if chlorine is present at 31,000 ppm or greater
215	215	53	19	0

Recommendations - Safety

- Determine site-specific attributes of natural and engineered materials with respect to radionuclide transport
- Determine site-specific attributes of natural and engineered materials with respect to limiting postclosure criticality
- Develop performance assessment models that can discern differences in waste isolation performance for direct disposal of commercial SNF in DPCs compared to packaging purpose-designed for disposal
- Investigate effects of using cementitious materials in repository construction

Recommendations – Engineering Feasibility

- Understand fuel characteristics that are age-dependent for the purposes of aging management
- Develop logistical model and perform logistical simulation
- Investigate vertical handling of canisters designed for horizontal handling
- Further development of surface-to-underground transport
- Further development of underground emplacement vehicle
- Develop self-shielding waste package
- Perform corrosion tests for DPC basket materials
- Perform corrosion tests for corrosion-resistant overpacks
- Develop more robust overpack reliability analysis and design overpack manufacturing process
- Establish underground stability for extended repository ventilation

Recommendations – Thermal Management

- Determine site-specific host rock thermal properties
- Establish backfill properties, degradation, and temperature tolerance (peak temperature tolerance of 200°C is desirable, as is high thermal conductivity)
- Investigate sinking of heavy packages in plastic host media (salt and perhaps clay)
- Develop process models for thermally driven coupled processes

Recommendations – Postclosure Criticality Control

- Criticality analysis for as-loaded DPCs
- Develop and justify stylized scenarios
- Develop in-package criticality consequence model*
- Develop burnup credit approach for BWR SNF
- Evaluate effects from radiolysis on basket degradation*
- Develop and evaluate DPC fillers for criticality control*
- Establish accuracy of reactor records for SNF

* Not needed for salt site