

Spent Fuel and Waste Science and Technology

SAND2018-9079PE

Overview of Dual-Purpose Canisters Disposal R&D

Prepared by Sandia National Laboratories technical staff, with input from consultants and other laboratories

Meeting with U.S. Nuclear Waste Technical Review Board Members and Staff

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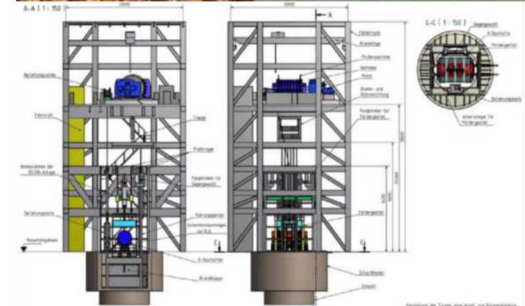
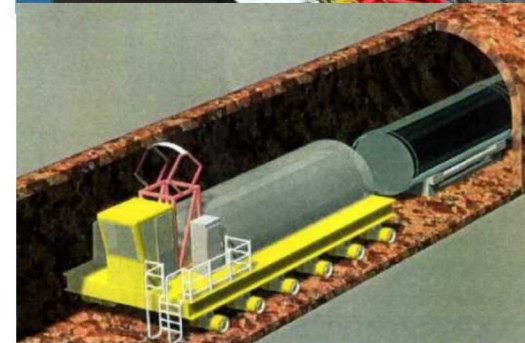
Dual-Purpose Canister Direct Disposal Background

- **Dry storage is an important solution for utility spent nuclear fuel (SNF) storage**
 - Dual-purpose canisters (DPCs) are loaded in fuel pools, dewatered, weld-sealed, and transferred into shielded storage casks or vaults
- **Most dry-storage canisters can be moved in shielded transportation casks**
- **~2,761 dry-storage canisters are now loaded with >30,000 MTU SNF**
- **DPCs were not designed, loaded or licensed for geologic disposal**
 - After disposal, some waste packages could eventually breach and fill (or partly fill) with water, so that DPC-based packages could be flooded
 - DPC fuel baskets are designed to control criticality for short-term operations (fuel pools) or transportation accidents
 - Aluminum-based neutron absorbing materials (e.g., Boral®) could readily corrode from long-term exposure to ground water

Facts About Potential Direct Disposal of SNF in DPC-Based Waste Packages

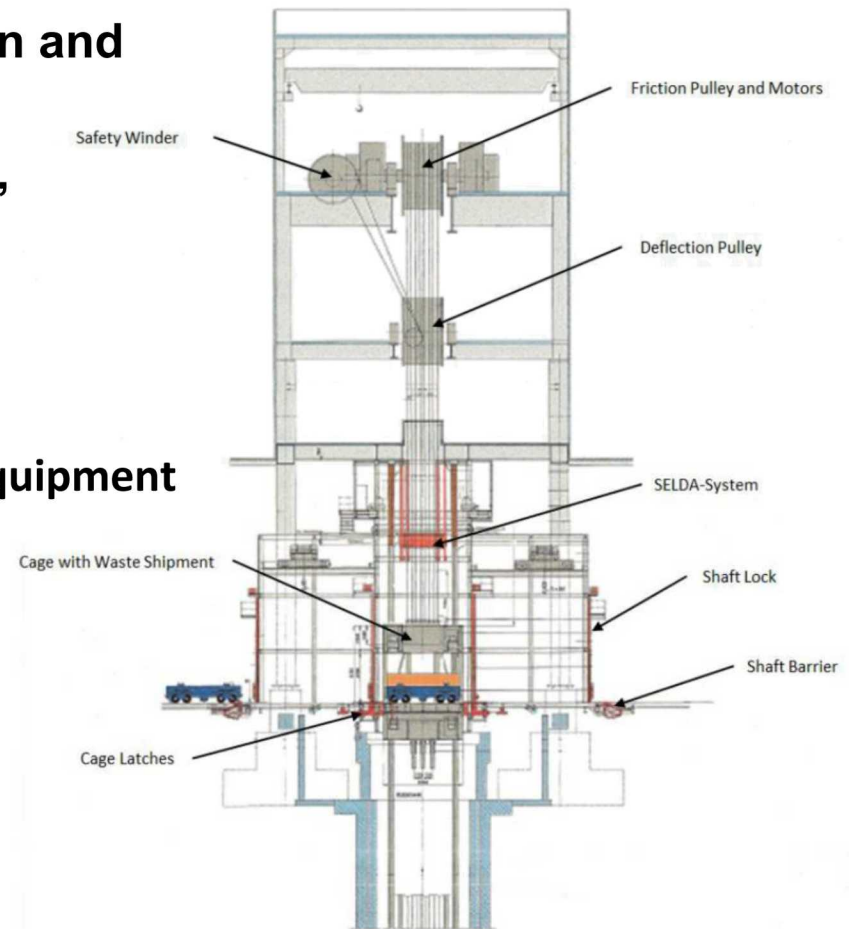
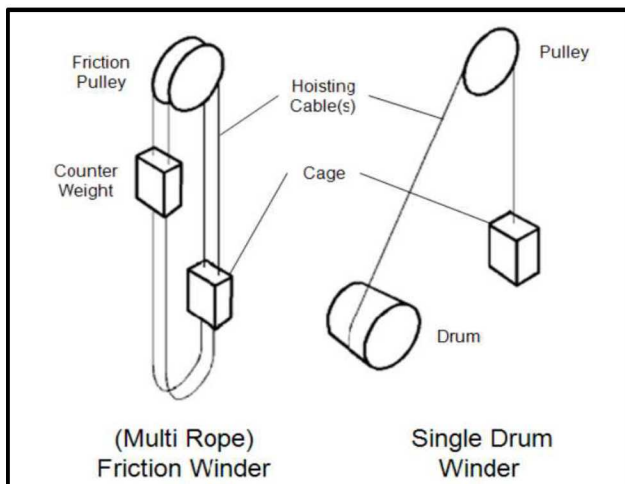
- DPCs weigh about the same as Yucca Mountain (YM) canisters sized for 21-pressurized water reactor (PWR) assemblies.
Loaded Magnastor® canister (NAC International) 37-PWR DPC (47 MT) vs. loaded YM 21-PWR canister (≤ 49.3 MT)
- DPCs are about the same size as YM canisters for commercial SNF.
Magnastor canister dimensional envelope (1.80 m D x 4.87 m L $\rightarrow$ 12.4 m³) vs. YM canister (1.69 m D x 5.39 m L $\rightarrow$ 12.1 m³).
- DPC-based waste packages could be lowered down a shaft with a large hoist.
A DPC package (~70 MT) with shield (+75 MT) + carriage would be less than the 175 MT payload for the “DIREGT” conceptual hoist design (BGE Tec).
- DPC-based packages could be disposed of in a salt repository.
*Size and weight are reasonable challenges for transport underground
Thermal management may require some aging but 98% of commercial fuel could be emplaced by 2130.
Creep models calibrated to recent low-stress, low-strain-rate data predict small amounts of sinking in halite, especially if interbeds are included.*

- **Handling/Packaging: Use Current Practices**
- **Surface-Underground Transport**
 - Spiral ramp (~10% grade, rubber-tire)
 - Linear ramp (>10% grade, funicular)
 - Shallow ramp ($\leq 3\%$ grade, standard rail)
 - Heavy shaft hoist
- **Drift Opening Stability Constraints**
 - Salt (a few years with little attention; longer with rock bolts and periodic maintenance)
 - Hard rock (50 years or longer)
 - Sedimentary (50 years may be feasible; longer may require special geologic settings)



Heavy Shaft Hoist Technology

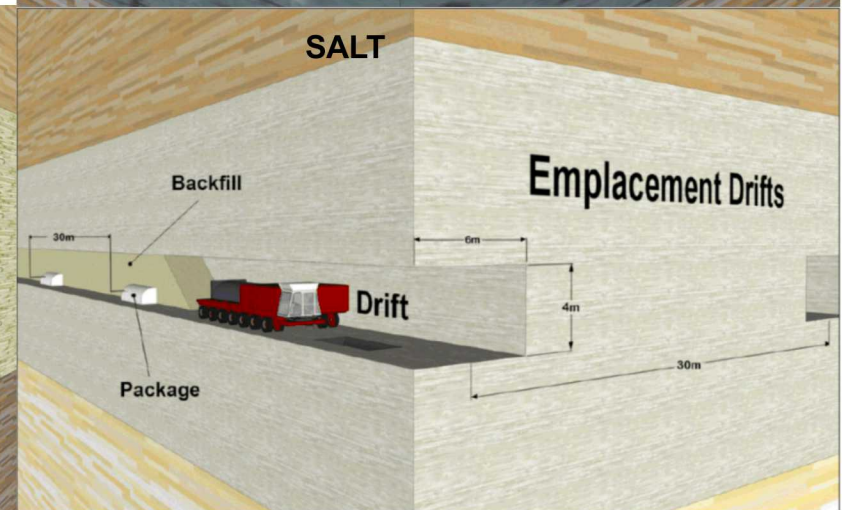
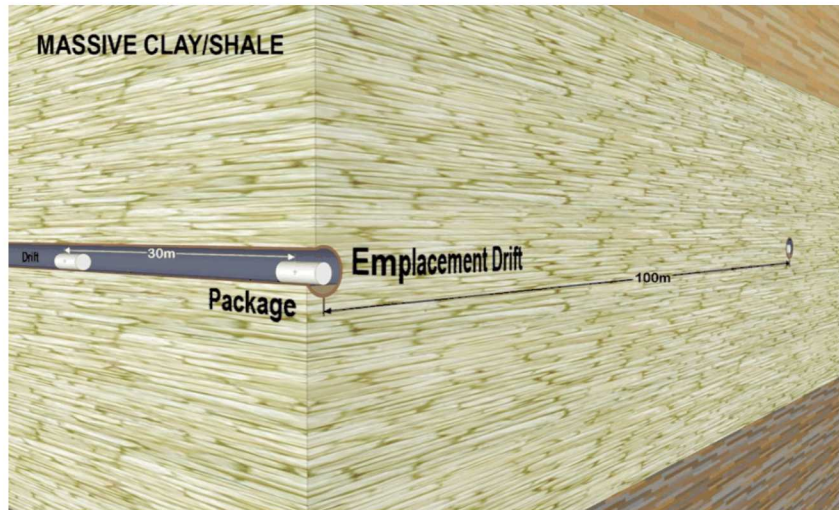
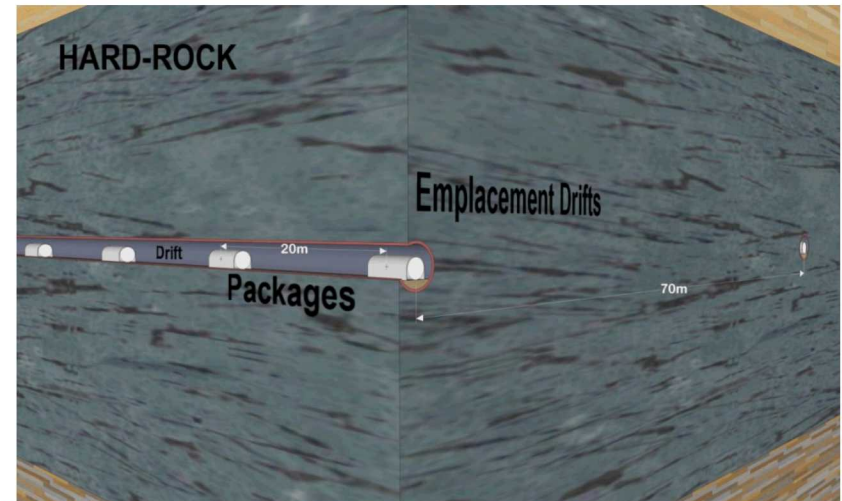
- Hoist R&D at Gorleben, Germany: Design and testing for 85 MT capacity (BGE Tec)
- Payload 175 MT for DPC-based package, shielding & cart
 - Koepke friction hoist, 6 cables (66 mm)
 - Counterweight 133 MT
 - 1 m/sec hoist speed with 800 kW winder
 - Order-of-magnitude cost about \$30M for equipment



Source: Hardin et al. 2013. FCRD-UFD-2013-000170 Rev. 0.

DPC Direct Disposal Concepts

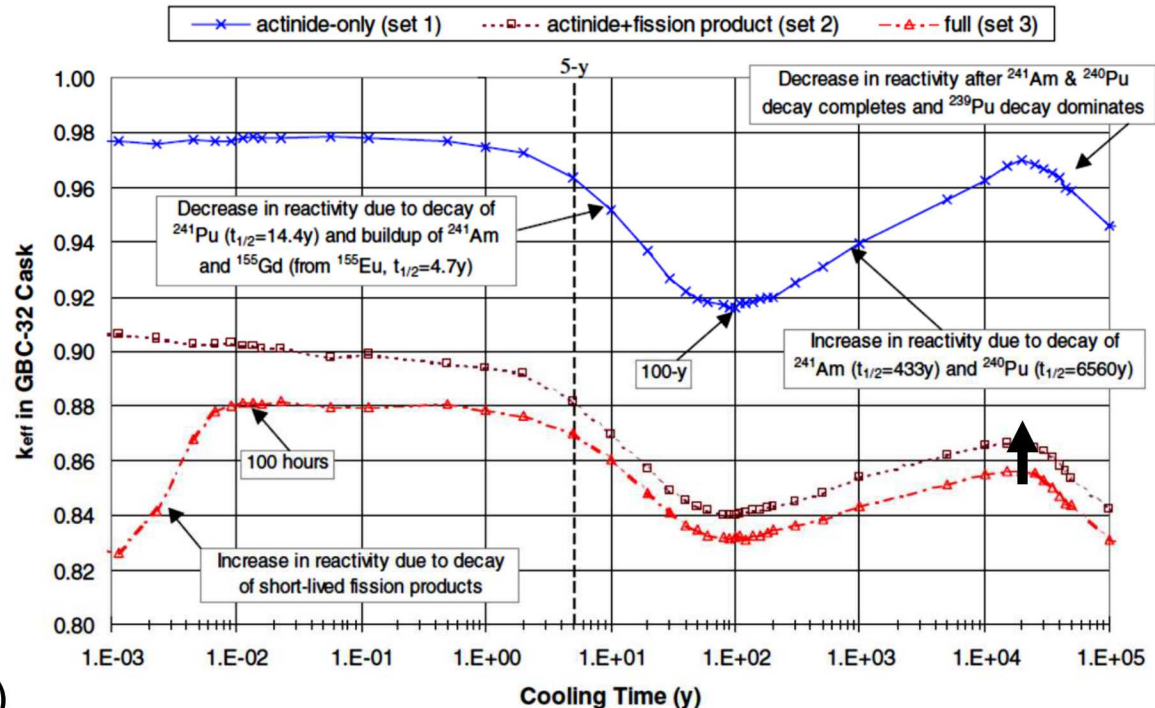
- Shaft or ramp transport
- In-drift emplacement
- Extended aging or repository ventilation (except salt)
- Backfill before closure (except hard rock unsaturated)
- Postclosure criticality control



(Hardin et al. 2013. FCRD-UFD-2013-000171 Rev. 1)

Postclosure Nuclear Criticality Control

- **Disposal Environment**
 - Groundwater availability
 - Chloride in groundwater
- **Moderator Exclusion**
 - Overpack integrity
- **Moderator Displacement**
 - Fillers
- **Add Neutron Absorbers**
 - Fillers (e.g., B_4C loaded)
 - Disposal control rods (as new DPCs are loaded)
- **Criticality Analysis Methodology**
 - Burnup credit, as-loaded, stylized degradation cases
 - Peak reactivity occurs at ~25,000 years

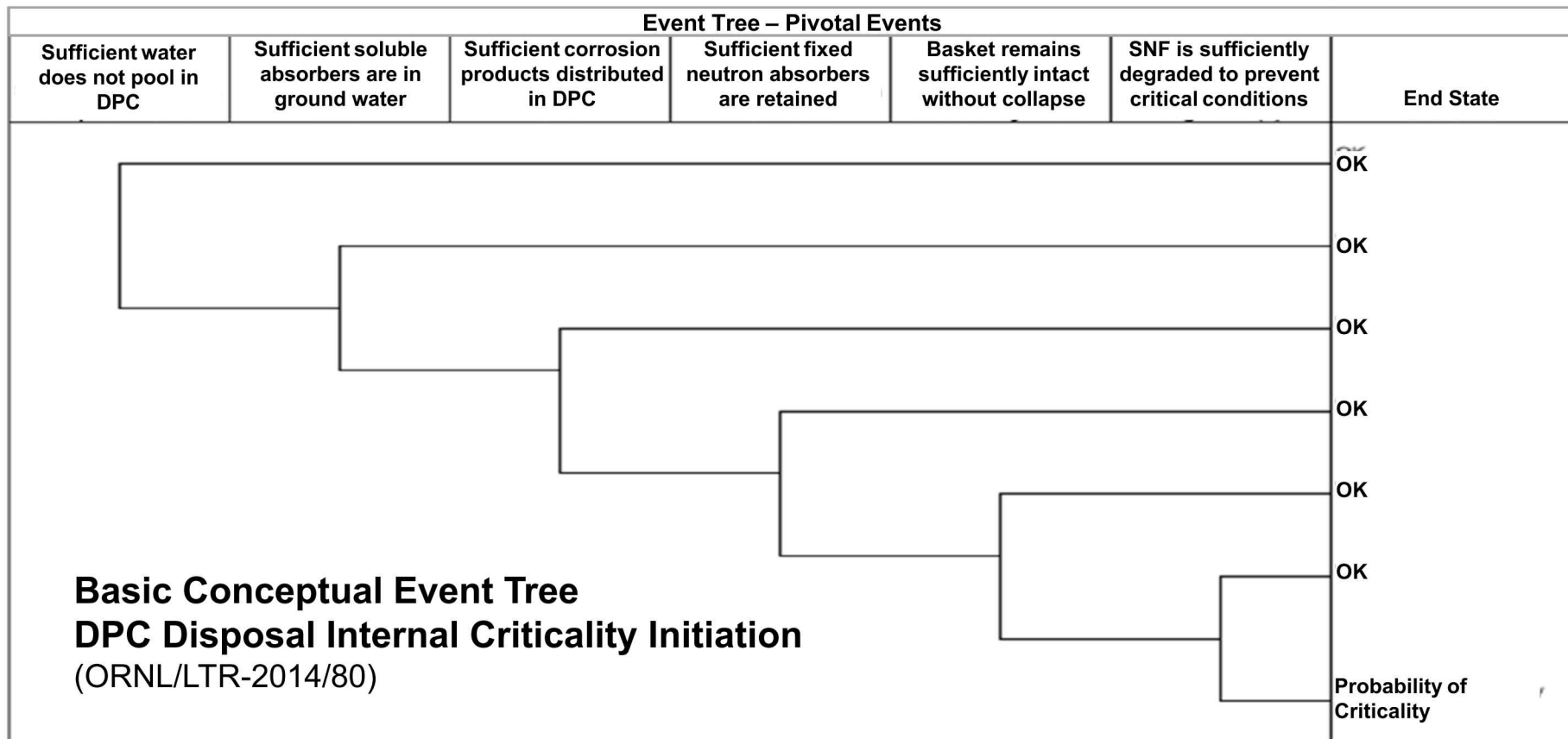


Neutron multiplication factor (k_{eff}) vs. time

Generic burnup credit (GBC) 32-PWR cask
PWR fuel (4% enriched,
40 GW-d/MT burnup)

Wagner and Parks 2001 (NUREG/CR-6781, Fig. 3)

DPC Disposal Criticality Initiators (low probability screening)



Example Analyses Supporting Low-Probability FEP Screening

- **Yucca Mountain License Application**
 - **Screening of Criticality FEPs for LA** (ANL-DS0-NU-000001 REV00A)
 - **Commercial SNF Waste Package Misload Analysis** (CAL-WHS-MD-00003 REV00A)
 - **Commercial SNF Igneous Scenario Criticality** (ANL-EBS-NU-000009 REV00)
 - **Commercial SNF Loading Curve Sensitivity Analysis** (ANL-EBS-NU-000010 REV 00)
- **Summary of Investigations on Technical Feasibility of Direct Disposal of DPCs** (SFWD-SFWST-2017-000045)

■ Technical evaluation results:

- Safety of workers and the public
- Engineering feasibility
- Thermal management
- Postclosure criticality control

No implementation barriers
although all existing DPCs may
not be disposable depending
on the disposal concept

■ Most favorable concepts: salt and hard rock-unsaturated

- Mainly due to thermal management and postclosure criticality control

■ Additional considerations important for direct disposal:

- Disposal overpack reliability estimates can be improved
- Features of existing DPC baskets will impact structural longevity
- Investigate DPC modifications for criticality control (e.g., fillers)
- Investigate screening postclosure criticality on low consequence in addition to low probability

Guidance from YM Criticality Topical Report (DOE YMP/TR-004Q) on Criticality Consequence Analysis

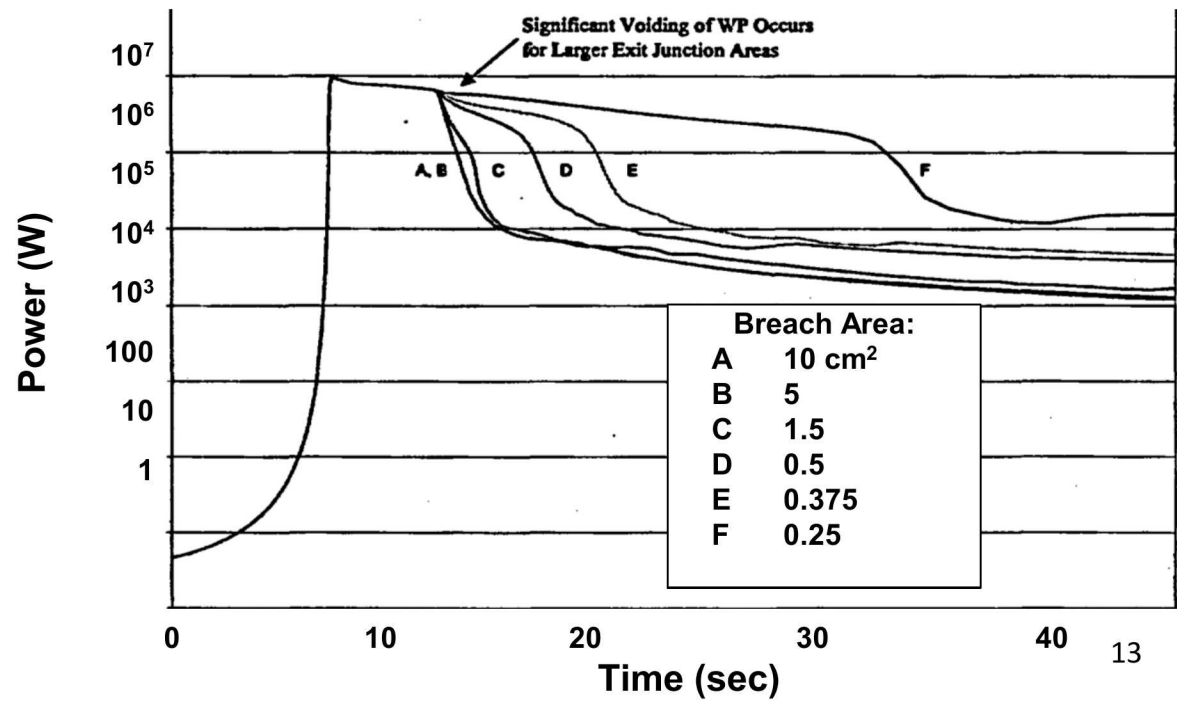
- **Potentially important effects from criticality on repository performance:**
 - Change in radionuclide inventory (from additional burnup)
 - Other effects on radionuclide transport, including
 - **Increased temperature**
 - **Fuel and container degradation (e.g., accelerated corrosion, mechanical damage, altered rates of radionuclide releases)**
- **Consider steady state and transient events**
 - Low-power events may be steady-state or pulsing
 - Transient events may be due to slow or rapid reactivity insertion
- **If postclosure criticality occurs, WF/WP degradation will likely truncate criticality event sequences**
- **Context (Rev. 02): One SNF canister design**

Background: Previous Simulations of Waste Package Criticality

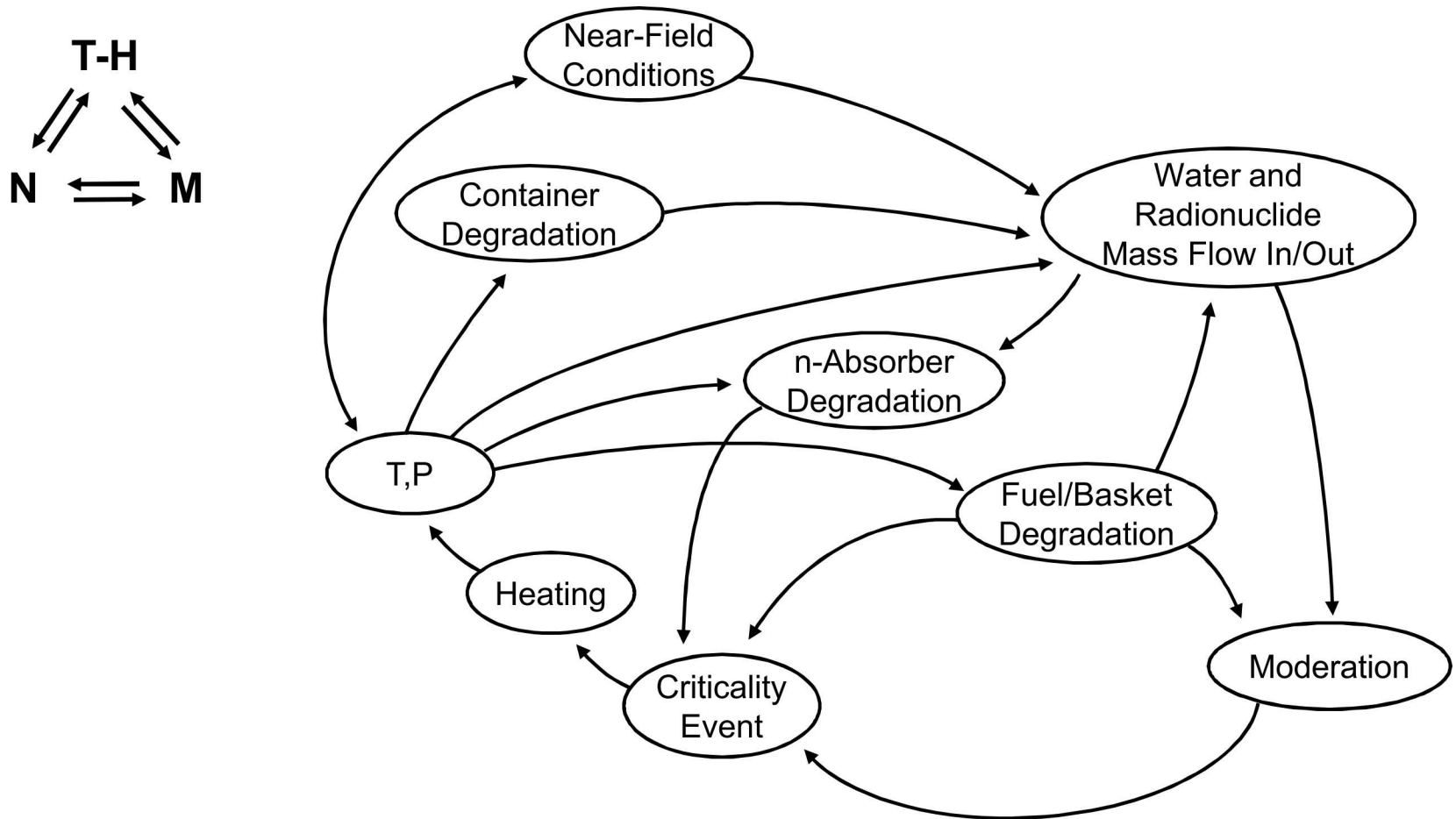
- **Criticality Consequence Analysis Involving Intact PWR SNF in a Degraded 21-PWR WP (BBA000000-01717-0200-00057 REV 00)**
- **Sensitivity Study of Reactivity Consequences to Waste Package Egress Area (CAL-EBS-NU-000001 REV00)**

Waste Package Power
vs. Time from RELAP5
Code Analysis of Fission
Power Histories for
Prompt (0.158 \$/sec)
Reactivity Insertion Rate
Parameterized by Waste
Package Breach Area

(CAL-EBS-NU-000001,
Figure 6-5)



Reference Coupling Scheme (DRAFT)



- **Criticality risk = probability (i.e., incidence) × consequence**
 - ⇒ Use of system-wide assessment with variability and uncertainties
- **How will criticality be affected by repository conditions?**
 - Spatial distribution and timing of waste package containment failures
 - Groundwater composition and rate of influx in to waste packages
 - Seismic hazard (where applicable)
- **How will the waste form and canister affect the incidence of criticality?**
 - Fuel enrichment & burnup
 - Fuel degradation rate vs. basket degradation rate
 - Gradual vs. rapid episodic degradation (sediment, collapse, ground motion)
 - Early package failure/manufacturing defects
- **How can internal criticality affect the repository as a system?**
 - Temperature evolution; fuel and container degradation; radionuclide release
 - Changes to the source term

Criticality Risk Screening Questions 2018 Independent Review *

- What is the threshold of mechanical energy that would impact repository performance?
- What is the threshold of temperature increase and heating duration that would impact repository performance?
- What is the threshold of concentration increase for radionuclides considered in the performance assessment (PA) (e.g., in the YM License Application) that would impact the regulatory dose estimate?
- What is the importance of radionuclides not already considered in the PA?
- What is the radiolysis threshold (mainly from neutrons) that would impact waste package chemistry?

* Alsaed, A. 2018. SFWD-SFWST-2018-000491 Rev. 0.

FY18-19 Planned Activities

- **Planned Activities:**

- Technical/Programmatic Solutions for Direct Disposal of SNF in DPCs
- Probabilistic Post-Closure DPC Criticality Consequence Analysis
- DPC Filler and Neutron Absorber Degradation R&D
- Multi-Physics Simulation of DPC Criticality

- **Expected Outcomes:**

- DPC disposition alternatives, R&D and resource needs
- Generic (non-site specific) preliminary PA model
- Evaluate feasibility for candidate filler materials
- Mechanistic multi-physics coupled models