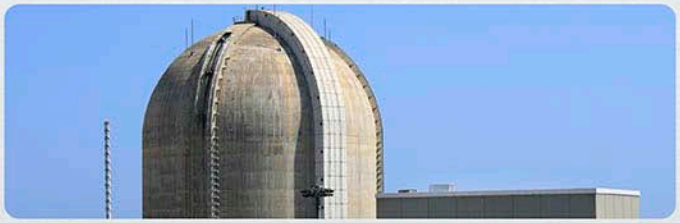
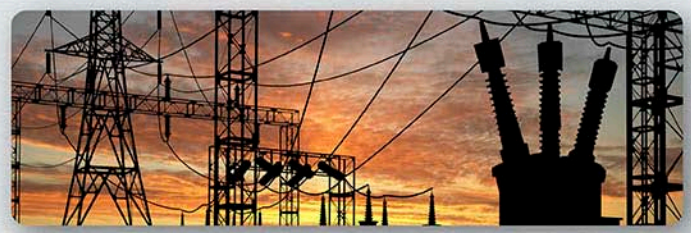


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Extended Storage: Research Perspective

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Guiding Principles

- Disposal or reprocessing not likely for decades
- Current regulations: up to 120 years combined wet/dry
  - 60 years wet storage; 60 years dry storage
- Global interest: Not just a U.S. issue
- Storage systems will have to perform intended function beyond current licensing period

Technical bases for dry storage >60 years not yet demonstrated

Functions of Storage and Transportation Systems

- Thermal performance
- Radiological protection
- Confinement
- Sub-criticality
- Retrievability

Can existing and future systems maintain these storage and transportation functions for many more decades?

Temperature-related Dry Storage System Degradation Mechanisms

- Dry storage systems
  - Degradation of neutron shielding
  - Concrete dry-out and cracking
  - Corrosion
- System internals
  - Fuel cladding creep caused by increased cladding ductility and increased stress
    - Due to higher temperatures causing higher pressures inside the cladding
  - Hydride reorientation in the spent fuel cladding
  - Corrosion

Changes as the System gets Older and Cooler

- Mostly good things
  - Reduced metal creep rates
  - Reduced corrosion rates
  - Reduced gamma and neutron radiation
- Potential negatives
  - Cask systems
    - Canister stress corrosion cracking (particularly in marine environments)
  - Internals
    - Additional hydride precipitation
    - Decreased cladding ductility
      - *Potentially* more susceptible to breakage during storage and transportation

EPRI Extended Storage Collaboration Program (ESCP)

- Purpose: Provide the technical bases to ensure continued safe, long-term used fuel storage and future transportability.
- Modeled on prior dry storage license extension research
- Participants: EPRI, NWTRB, NRC, DOE, NEI, utilities, vendors, international
- Phased approach
  - Phase 1: Review current technical bases and conduct gap analysis for storage systems
  - Phase 2: Conduct experiments, field studies, and additional analyses to address gaps
  - Phase 3: Coordinate research that results in a program documenting the performance of a dry storage system loaded with high burnup fuel (>45 GWd/MTU)

Current ESCP Status

- Phase 1 gap analyses well under way
  - NWTRB analysis completed in 2010
  - Preliminary gap analyses presented by DOE and NRC
  - Summary of recent ESCP activity and gap analyses in EPRI report 1022914 (August 2011)
    - EPRI report available to the public at: http://my.epri.com/portal/server.pt?Abstract_id=000000000001022914
- Three primary extended storage gaps identified in December 2010
  - Cladding integrity
  - Welded stainless steel canisters
  - Concrete

Confinement – The Number 1 Priority

- Three confinement barriers are considered
  - Primary barriers:
    - Bolted systems: seals and bolts
      - Significant R&D completed or underway (Germany and Japan)
    - Welded stainless steel systems: welded SS canister
      - External inspection a common desire
      - EPRI work on NDE tools ongoing
  - Secondary barrier: fuel cladding
    - Most cladding intact, but some is already degraded
    - Cladding integrity contributes to sub-criticality and retrievability

Criteria for Prioritization of R&D

- DOE preliminary criteria:
  1. Whether existing data are sufficient to evaluate the degradation mechanism and its impact on an “important to safety” (ITS) SSC
  2. The likelihood of occurrence of the degradation mechanism during extended storage
  3. Ease of remediation of the degraded SSC such that it continues to provide it safety function
  4. The significance of the potential consequences that may result from the degradation mechanism.
- EPRI preliminary criteria:
  1. The importance to maintaining the safety functions with particular emphasis on the confinement safety function.
  2. The amount of R&D that has already been completed.
  3. Whether the data gap is the subject of significant, on-going research.
  4. The ability to fairly easily detect, inspect, or mitigate degradation of the safety function(s) affected by the long-term process being considered.

High Priority Gaps Requiring R&D

- Common high priority in the US: welded canister (primarily SS) degradation
  - Effect of marine environments: stress corrosion cracking (SCC)

- Other High Priority Items
  - DOE:
    - Delayed Hydrogen Cracking (DHC)
    - Bolted cask metallic seals and bolts corrosion
  - NRC: Bolted cask metallic seals
  - Outside the US: bolted cask metallic seals

Recommended ESCP Expert Groups Identified at May and June 2011 Meetings

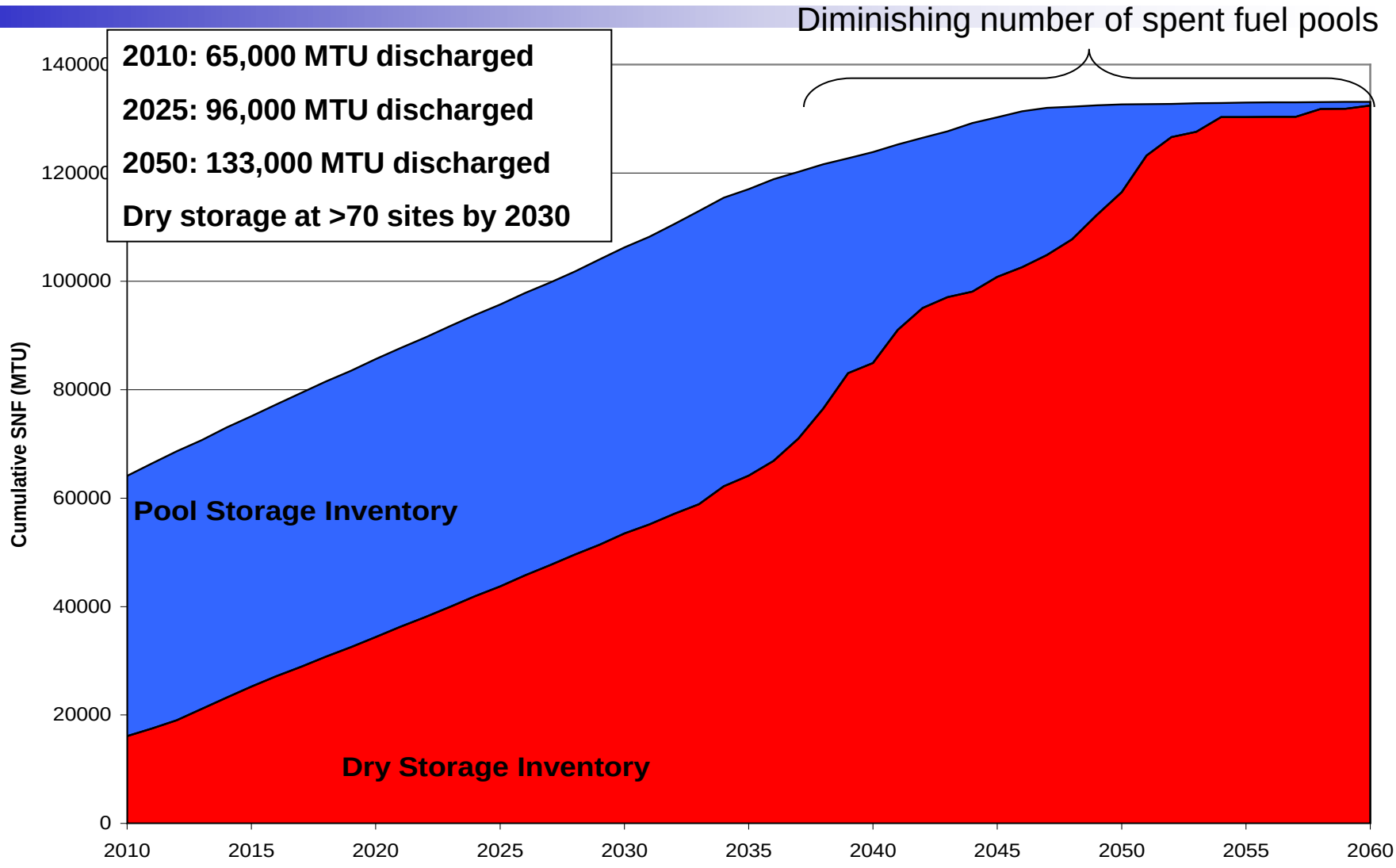
- Fuel/Internals
- Confinement (Canister/Cask) Systems
  - Welded stainless steel canisters
  - Bolted cask seals and bolts (international lead)
- Bolted cask neutron shielding (international lead)
- Concrete Systems
- Demonstration Project

EPRI Near-Term Work on Welded SS Canisters: Develop NDE Tool(s) for In Situ Inspection

- Options for inspection of outside of canisters:
  - Visual
  - Weld cracking
- Develop tools for specific casks based on
  - Volunteer utility/utilities
  - Prefer coastal sites (marine environments)
  - Conditions that may support SCC
    - Time in storage
    - Sufficiently high relative humidity on canister surface
- Target timeline: inspection of one or two canisters by end of 2012

Thoughts on what the US Industry Wants from DOE (re Extended Storage)

Cumulative U.S. Commercial Spent Nuclear Fuel Inventories – 2010 to 2060 (assumes no nuclear expansion, 60-year life)



Aug 2010, Energy Resources International, Inc.

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Extended Storage Aging Management R&D Needs – Near Term

Maximize life of existing systems and ensure transportability:

- Additional data and analyses of long-term degradation mechanisms (ESCP Program). Specific examples:
  - Hydride reorientation
  - Advanced cladding properties
  - SS canister corrosion
- Develop regulatory framework for >60 years
- Enhanced monitoring and inspection

Extended Storage Aging Management R&D Needs – Intermediate and Long-Term

- Intermediate-term: Evaluate mitigation/design options
  - e.g., anti-corrosion coatings; new cask designs

- Long-term: Develop risk-informed approach to extended storage
  - When does the worker and public dose risk of continued storage in existing systems exceed the economic and worker dose risk of transferring used fuel into a new system?

- **Industry expects DOE to take the lead in all these areas – with appropriate industry collaboration**

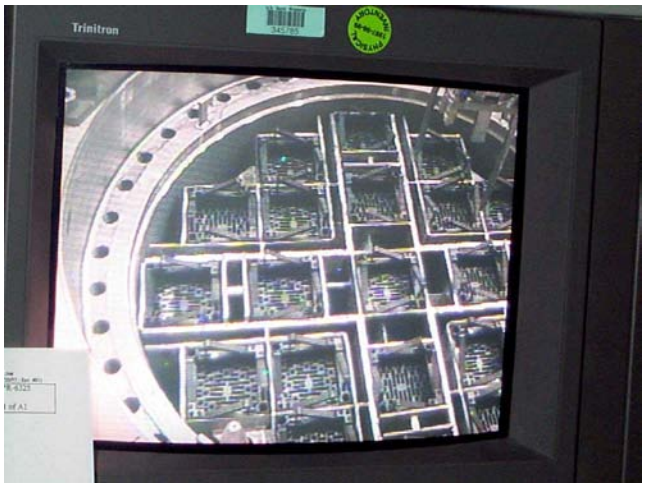
Thoughts on "Experimental Work": Two Areas of Research

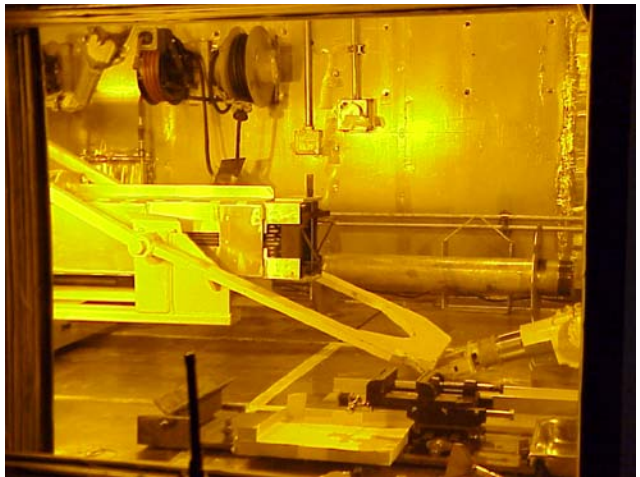
1. Survey existing cask and pool systems
- Detailed inspections
- Take samples to inspect for degradation. Possibilities:
  - Concrete (cores?)
  - Canister gas
  - Keep monitoring CASTOR V cask at INL
  - *SS corrosion investigation (focus of EPRI nearer-term work)*
  - Pool liner leakage work?

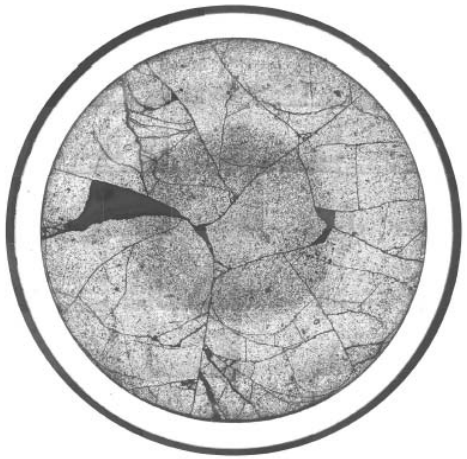
“Experimental Work”: Research Area #2

2. Dry cask storage confirmatory demo using high BU used fuel

- Same idea as was done in the ’80s and early ’90s using lower BU used fuel
  - Answer questions about *high BU* cask system and fuel behavior
- Obtain one or more casks licensed for high BU storage and transportation
- Pre-characterize “sister” rods
- Load with high BU used fuel at the upper limits of the license condition (highest BU, decay heat, source term allowed)
- Modify to allow for reopening and cavity gas and temperature sampling over many years
- After “several” years: reopen, take rods for destructive examination







EXAMPLE: Estimated Duration and Costs [$M] for Confirmatory Program Options for High BU Fuel (from EPRI report 1007872, 2003)

Activity	Option A: Augment Existing Exam Program	Option B: Utility ISFSI Followed by Laboratory Examination	Option C: Laboratory Storage and Examination
Estimated program duration [yr]	*5*	*12*	*12*
Program management	1	4	4
Demonstration storage system	0	~5	~7
Pool-side NDE	>0	>0.2	>0.2
Shipping to laboratory	0.3	0.3	0.3 to >1
Dry storage demonstration period with periodic monitoring and surveillance	0	1.5	1.5
Post-storage fuel rod examination	3	4 to 7	4 to 7
Post-test disposal and cleanup	1	1	>1
TOTAL	~5	~15 to 20	~18 to 21

Problem: No Place Like the INL TAN Hot Cell Exists Any More

- **DOE needs to provide capability lost due to TAN Hot Cell decommissioning**
- Otherwise
  - The test will have to be done using a spent fuel pool
    - Potential changes in storage system (esp. used fuel) properties if rewetted
  - Or conduct a test using only a limited number of assemblies so the mini-cask can fit into an existing hot cell
    - Not ideal: can introduce experimental artifacts

Unknown: How Long Systems will Last or When DOE will Take Used Fuel

- **DOE must develop, license and demonstrate one (or more) systems to repackage used fuel in lieu of pool availability**
  - Full or partial repackaging
    - Must be a “dry” transfer system as spent fuel pools eventually become decommissioned
  - Overpackaging
  - Something else?
- Dry transfer system should be developed sooner rather than later to maintain confidence in long-term interim management of used fuel

Summary of What the Industry Wants from DOE - Specifics

- Provide the majority of the overall R&D funding, but remain collaborative
- Work with industry to continue to obtain high burnup used fuel properties and long-term behavior for transportation
- Provide a new facility like the decommissioned hot cell facility at INL to handle commercial full-size dry storage casks containing high burnup fuel for the confirmatory test(s)
  - Or wet or “mini-cask” approach
- Develop ownership transfer plan for used fuel used in experiments
- Must have a contingency plan
  - Develop, license, and demonstrate one or more used fuel transfer systems compatible with existing infrastructure

What Industry Wants from DOE - Processes

- DOE program should be oriented to support the timely movement of UNF off reactor sites
- Transparency and timeliness
  - DOE's plans and processes should be open for public comments
  - Release reports without delay
  - Prioritize R&D with licensing needs
    - DOE schedule should be cognizant of nearer-term license extension regulatory issues (high BU fuel?)
- DOE extended storage program should look for synergies with centralized interim storage
  - E.g., extended storage R&D co-located with centralized storage

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