

**EPRI** | ELECTRIC POWER RESEARCH INSTITUTE

## Extended Used Fuel and HLW Storage *(followed by transportation)*

John Kessler, Keith Waldrop

NRC Regulatory Information Conference, Rockville MD  
 Session Title: "Considerations for Long-Term Storage of Spent Nuclear Fuel on the Way to Disposal"  
 March 14, 2012

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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**

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### 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?**

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### Aging Management R&D Needs

- Near-term: Maximize life of existing systems and ensure transportability
  - Additional data and analyses of long-term degradation mechanisms
  - Enhanced monitoring and inspection
- Intermediate-term: Evaluate mitigation/design options
- “Eventually” (more costly, higher worker dose)
  - Repackaging
  - Over-packaging

When is “eventually”?

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### Ultimate Goals of the Extended Storage Project

- Improve technical bases for storage *in existing systems* well beyond 60 years
- Support development of industry aging management plans
  - Inspection (What? When?)
  - Mitigation
  - Repair
  - Replacement
- Provide data for new cask designs
- Add to confidence used fuel and HLW can be safely transported after decades of storage

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### EPRI-led Extended Storage Collaboration Program (ESCP)

- Mission Statement: “Provide the technical bases to ensure continued safe, long-term used fuel storage and future transportability”
- Participants: EPRI, NWTRB, NRC, DOE, NEI, utilities, vendors, international (~20 countries, IAEA)
- Phased approach
  - ✓ Phase 1: Review current technical bases and conduct gap analysis for storage systems
    - ✓ (NWTRB, DOE, NRC, EPRI, Japan, Spain, ...)
  - 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)

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### Value of Collaborative Extended Storage R&D Recognized by Others

- NWTRB letter to DOE Undersecretary Lyons (12/30/11):
  - “The Board believes that ESCP is an extremely valuable undertaking and strongly endorses DOE’s continued active participation in the collaboration. As noted above, the Board recommends that DOE provide adequate resources to support ESCP’s objectives.”
- Blue Ribbon Commission Final Report, 1/26/12:
  - “Assuring safe and secure storage of SNF and HLW over extended periods of time will require continued public and private efforts—including efforts by the NRC, DOE, and industry organizations such as EPRI—to conduct rigorous research and oversight and continuously incorporate lessons learned from new developments or events.”

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### Blue Ribbon Commission Final Report (1/26/12, continued)

- “Specifically we urge continued work by the NRC, DOE, industry organizations such as EPRI, and others to explore fuel degradation mechanisms, identify unanticipated problems with extended fuel storage (i.e., unexpected corrosion rates), better understand the behavior of dry storage systems and their contents over time... .”
- “Some of these issues will be addressed as part of the Extended Storage Collaboration Program that EPRI has launched ... to research the technical basis for long-term dry storage of SNF.”

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### Main Elements of EPRI’s Extended Storage Program

- ✓ Establish international collaboration to share information and resources
  - ESCP
  - Integration with IAEA and NEA efforts underway
- ✓ Identify and prioritize R&D “gaps”
- Work with ESCP participants to address the highest priority gaps
  - EPRI’s only “high” priority gap: SS canister degradation – potentially enhanced by “marine environments”
- Other R&D needed to firmly establish bases: literature mining; modeling; experiments; inspections

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## SCC of Welded Canisters – What do we know?

### Several studies show SCC of canister materials is possible

- NUREG/CR 7030, *Atmospheric stress corrosion cracking susceptibility of welded and unwelded 304, 304L, and 316L austenitic stainless steels commonly used for dry cask storage containers exposed to marine environments.*
- CRIEPI - S. Koizumi and K. Shirai, "Demonstration Program of Long-Term Storage (FY2004-2008) – SCC of MPC under the Condition of Sea Salt Deposition," presentation to the US NRC, November 8-9, 2004, Washington, DC.
- Kure Beach - INCO, "Marine Atmospheric Corrosion," A-1275, New York, NY, March 1978

### All extreme conditions, mostly in lab

What are actual canister conditions?  
Can SCC occur under actual conditions?

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## Road to Establishing an Industry SS Canister Aging Management Plan

- Goals
  - Develop aging management plan (inspections, maintenance, additional inspections, replacement)
  - Obtain regulatory approval for plan
- Technical needs
  - Determine conditions required for SS corrosion, SCC
    - Literature review
    - Supplement with experiments and modeling
    - Corroborate with in situ inspections
  - Identify which canisters that have those conditions
    - Time-, position-, material-dependent

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## Conditions that May Support SS Corrosion

- Salt deposited on SS surfaces ("marine environments" issue)
- Right combination of canister surface temperature and humidity with salts present ("deliquescence")
  - CRIEPI: temperature between ~40C and ~80C
  - Would be valuable to have additional studies
- Time
- R&D – in combination with field measurements – needed to determine these conditions

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**All Pieces of the SS Corrosion “Story” Need to be Available for an Aging Management Plan**

1. Amount of salt deposited on the SS canister surfaces
2. Canister surface temperature
3. Humidity at the canister surface
4. Amount of time in the “right” conditions

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**Industry-Wide SS Canister Inspection Plan Would then be Possible**

- Determine if an inspection needs to be done for each, individual canister as a function of:
  - Storage system design
  - Location
  - Decay heat (assembly type and operating history)
  - Time loaded
- Additional canisters will need to be considered for inspection as time progresses
- Could require periodic, non-invasive data collection, such as:
  - Temperature, RH, salt/dust content at air inlet and outlet
  - Use of coupons

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**Large Number of Factors Requires Significant Data Collection**

- Additional experiments to determine conditions required to cause corrosion/SCC
  - Obtain canister samples – including weldments (304, 316, different weld processes affecting residual stresses, ...)
- Separate chemical models to predict what deliquescent brines will exist and at what temperature/RH – requires confirmatory experiments
- Multiple welded canister storage system designs
- Multiple sites (focus on coastal, but one or two inland sites, too)

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### In Situ SS Canister Inspection Data Desired

- Air inlet (time-averaged)
  - Temperature
  - RH
  - Salt content
- Canister properties at various positions
  - Surface temperature
  - Salt/dust content and composition
- Visual inspections for signs of corrosion
- Possibly in the future:
  - NDE for SCC
  - More “aggressive” inspections (if really needed)

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### EPRI Near-Term SS Canister Inspection Plans

#### Lead plant: Calvert Cliffs

- Chosen due to timing (June 2012)

#### Scope of inspections:

- Visual
- Temperature
- Humidity
- Surface contaminants

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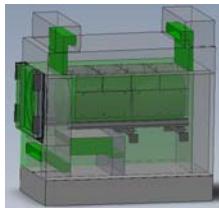
### Calvert Cliffs Inspection Plans

#### Through outlet

- Visual

#### Through front

- Surface contaminants
- Temperature
- Requires temporary shielding



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## EPRI is Looking for Additional Industry Volunteers

- Effects of marine environments
  - We need marine environments!
  - Salt concentration measurement devices



Outside view  
 Inside view  
 Size(Box of measurement device): 700 × 700 × 400mm  
 Weight: 60 kg  
 Power supply: 100V (20A)



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## SS Canister Degradation Issues Requiring Volunteers (continued)

- Loaded welded canister systems (horizontal and vertical) to test out NDE device(s) (visual, phased array)
  - Insert device through air inlets or outlets, maybe through partially open lid?
- Take swipes to measure salt deposition and composition
- Measure canister surface temperatures to help benchmark “best estimate” thermal models by
  - DOE
  - Vendors
  - Others



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## Other Extended Storage Research

### DOE Labs

- Corrosion products chemical evolution model
- Additional “CRIEPI-like” experiments to define window of susceptibility
- Co-fund EPRI inspections

### NEUP

- Literature search
- Characterize chemical environment
- Characterize mechanical environment

### NRC

- Additional “CRIEPI-like” experiments to define window of susceptibility
- Co-fund EPRI inspections

### IAEA

- Literature search
- Additional experiments (e.g., delayed hydride cracking)

### Others (Japan, Germany,...)

- Bolted system degradation experiments



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### Long-term Component of EPRI's Extended Storage Roadmap

- Co-fund a *confirmatory* demonstration program for extended storage of high burnup used fuel
  - Load high burnup used fuel in a fully-instrumented canister or cask for long-term monitoring and periodic inspection
    - Internal gas composition
    - Temperatures
  - Re-open after one or more decades
  - Performed in conjunction with previous or concurrent smaller-scale experiments, tests, inspections, and modeling efforts

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