

# Used Fuel Disposition Campaign

## Separate Effects and Small-Scale Testing in Support of Extended Dry Storage

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- **The Used Fuel Disposition Campaign (UFDC) has established a Storage and Transportation research and development task to address issues associated with extended used nuclear fuel (UNF) storage and transportation.**
- **Near term objectives include development of the technical bases:**
  - To support the continued storage of UNF for extended periods.
  - For retrieval of UNF after extended storage.
  - For transport of high burnup fuel; as well as low burnup fuel after dry storage.
- **The first step in establishing the technical bases for storage and transportation was to determine the technical data gaps that need to be addressed.**
  - These analyses are documented in:
    - *Gap Analysis to Support Extended Storage of Used Nuclear Fuel, Revision 0*, January 2012, FCRD-USED-2011-000136
    - *Used Nuclear Fuel Storage and Transportation Data Gap Prioritization, Draft*, April, 2012, FCRD-USED-2012-000109
    - *Review Of Used Nuclear Fuel Storage and Transportation Technical Gap Analyses*, July, 2012, FCRD-USED-2012-000215

# Used Fuel Disposition

## Data Gap Summarization

Gap	Priority	Gap	Priority
Thermal Profiles	1	Neutron poisons – Thermal aging	7
Stress Profiles	1	Moderator Exclusion	8
Monitoring – External	2	Cladding – Delayed Hydride Cracking	9
Welded canister – Atmospheric corrosion	2	Examination of the fuel at the INL	10
Fuel Transfer Options	3	Cladding – Creep	11
Monitoring – Internal	4	Fuel Assembly Hardware – SCC	11
Welded canister – Aqueous corrosion	5	Neutron poisons – Embrittlement	11
Bolted casks – Fatigue of seals & bolts	5	Cladding – Annealing of radiation damage	12
Bolted casks – Atmospheric corrosion	5	Cladding – Oxidation	13
Bolted casks – Aqueous corrosion	5	Neutron poisons – Creep	13
Drying Issues	6	Neutron poisons – Corrosion	13
Burnup Credit	7	Overpack – Freeze-thaw	14
Cladding – Hydride reorientation	7	Overpack – Corrosion of embedded steel	14

*Imminent need*

*Immediate to facilitate demonstration early start*

*Near-term High or Very High*

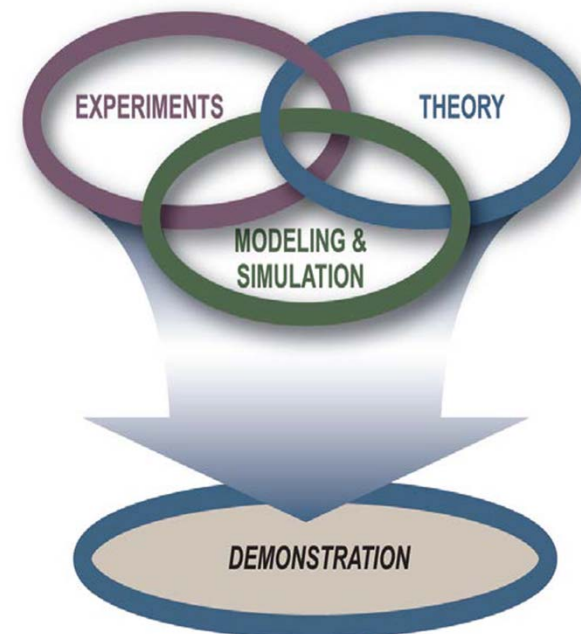
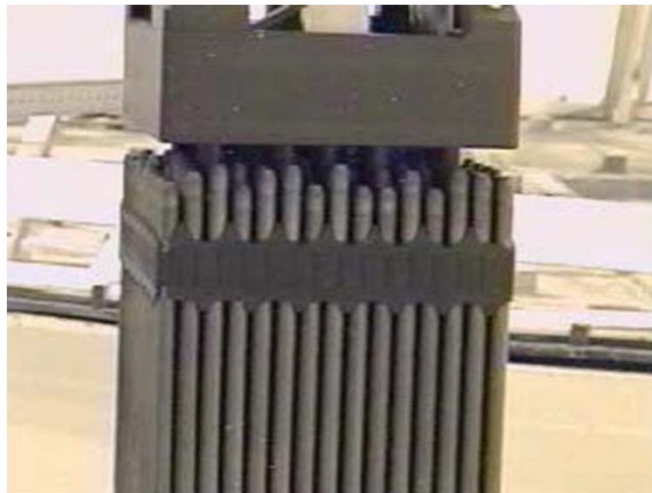
*Long-term High*

*Near-term Medium or Medium High*

*Long-term Medium*

## Data Gap Closure

- Closing data gaps within a science-based, engineering-driven approach for extended storage and transportation, is largely focused on the engineering-driven portion of the approach.
  - Data must be collected, especially for high burnup UNF and newer alloys and materials, and predictive models must be developed and then confirmed through demonstration
  - However a more thorough science-based understanding and mechanistic models are needed when mechanisms are not well understood, particularly for long storage periods.
    - For example, low-temperature, low-stress cladding creep



## ■ **Separate Effects Tests (SET)**

- Focused on determining the effects of individual variables on degradation mechanisms
- Typically smaller samples (taken from fuel pins, assembly hardware, etc.), but up to a full fuel pin in size
- Can involve surrogates developed to test single property effects
- Data derived from SETs must be correlated with the system they are intended to describe

## ■ **Small-Scale Tests (SST)**

- Used to investigate integral effects of multiple variables without going to a very large test
- Tests are fuel assembly-sized or smaller
- Provides an accessible and interactive platform for testing

## ■ **Engineering-Scale Demonstration (ESD)**

- Focused on testing a full-sized storage cask system, under prototypic conditions
- DOE has issued RFP DE-SOL-0005019 to solicit proposals for performing an ESD

## ■ **In-Service Inspections**

- Gathers performance data from existing dry storage systems
- EPRI is leading many of these efforts

## ■ **Modeling and Simulation (M&S)**

- Focused primarily of utilizing existing codes to analyze data and develop predictive models of material behavior. New codes will be developed as needed
- Efforts are intended to link all testing scales together

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## Quick Status

Integration of all scales of testing and modeling and simulation is essential to closing data gaps.

### ■ SETs

- Many tests are ongoing

### ■ SSTs

- In planning

### ■ ESD

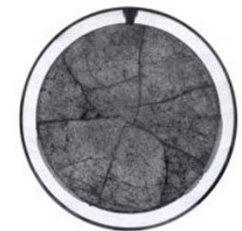
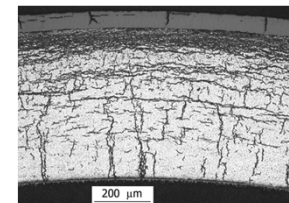
- RFP issued to initiate a demonstration within the next 2-3 years

### ■ In-Service Inspections

- Ongoing, Calvert Cliffs inspection performed in summer 2012
- EPRI hopeful for up to three inspections in 2013

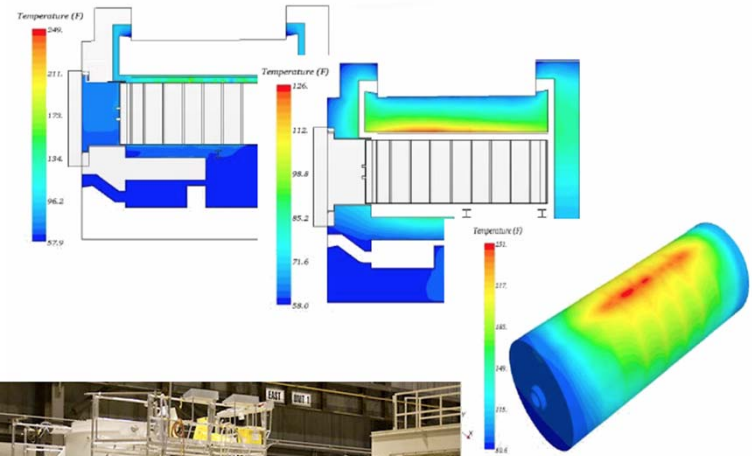
### ■ M&S

- Thermal modeling of casks and storage systems ongoing
- Mechanical properties modeling of casks, internal constituents, and storage systems ongoing
- Incorporation of uncertainty quantification to help with understanding long-term behavior of materials as related to extended storage and transportation has been initiated.



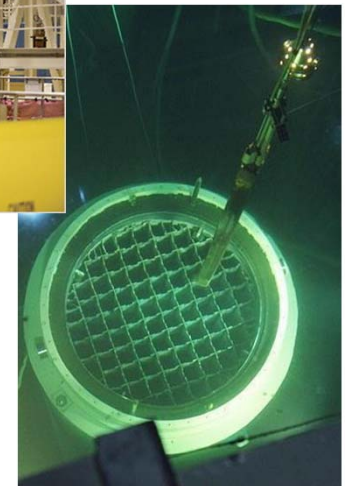
### ■ Gap – Thermal Profiles

- Data sources
  - *In-Service Inspection, e.g. temperature measurements taken from casks at Calvert Cliffs in 2012*
  - *Thermal modeling of cask temperatures conducted by PNNL in 2012*



### ■ Gap – Drying Issues

- Data Sources
  - *In-Service Inspection, humidity measurement during vacuum drying (water removal rate)*
  - *Small Scale Testing, monitor water partial pressure during fuel acquisition or other specific in-vessel sensors*
  - *Engineering-Scale Demonstration, humidity measurements or other specific in-vessel sensors*
  - *Modeling and Simulation, to predict residual water and water removal rates*



## **Highlights of Separate Effects Testing for 2013**

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- Ring Compression Testing is yielding mechanical properties data from high burnup used nuclear fuel. Provides insight into the effect of hydride reorientation on mechanical properties
- DBTT testing is yielding the ductile-brittle-transition-temperature of clad as a function of drying temperature and stress
- Bend Testing will yield data on bending strength of ‘complete’ used fuel segments (i.e. clad with fuel still inside)
- Develop strategy to acquire additional high burnup used fuel to support testing program
- Borated steel studies to develop an understanding of how boron affects the thermal sensitization of stainless steel
- Perform drying studies with industry that will yield information on water removal rates from casks and determine residual water following drying
- Perform container/waste package corrosion tests to determine corrosion rates of these materials



# Used Fuel Disposition

## Planning for Small Scale Testing

- **It has been proposed that a long-term testing platform for used nuclear fuel be developed.**
  - Duplicate large storage cask environments (e.g. heat decay, dose rates, materials, etc.)
  - Up to a full assembly in size (i.e. hundreds of fuel pins)
  - Designed to accommodate different fuel clads; both PWR and BWR
  - Designed for ‘easy’ opening, ‘easy’ instrumentation, ‘easy’ inspection
  - Test Plan due to DOE for consideration in late FY 2013
- **Logistics**
  - Fuel acquisition, drying, shipping
  - Where to locate such a test
  - Cost and schedule versus benefits
- **Benefits**
  - Provide HBU fuel samples to the testing program that have been conditioned similar to fuel in commercial dry storage casks
  - Allows sampling and testing of hardware and ‘cask’ materials
  - Test bed for instrumentation development
  - Data collection from full fuel pins as they age; e.g. creep
  - Supports multiple data gap determinations



NAC-LWT cask is sized similar to a small scale test

## When is Testing Complete?

- **Determination of when there is enough data to close a data gap can be elusive.**
  - Tendency that more is always better
  - But more in the world of nuclear related research and development is not inexpensive
    - *This is why there is such an emphasis on collaboration, both within the U.S. and internationally*
- **Within the UFDC we have initiated a new activity, *Modeling and Simulation and Experimental Integration with Uncertainty Quantification***
  - The first ‘project’ to be undertaken focuses on normal transportation of UNF. The hypothesis for this project is “Can fuel assemblies be transported following extended storage?”
  - This could be solved with an extensive testing program that might artificially age fuel and assembly hardware or vibration test aged fuel assemblies at the end of storage life.
    - *We should not wait until the end of storage to make that determination, and extensive testing is prohibitive (cost, schedule)*
  - Instead, we redefine the problem statement slightly: “What are the normal transportation loads that a fuel assembly will experience and do those loads challenge the mechanical strength of an assembly?”
    - Normal transportation loads can be determined
    - Use sensitive analysis to quantify uncertainties
    - Confirmation testing can be performed as needed to verify or validate the results
  - This methodology will be used in other areas as appropriate.

- **The UFDC has identified technical data gaps that will be closed in support of extended storage and transportation of used nuclear fuel.**
- **Gap closure depends on a combination of testing scales and modeling and simulation**
- **Separate effects and small-scale testing are an important part of the strategy for gap closure.**
  - Separate effects tests are either ongoing or are being developed
  - A small-scale test is in the planning stages for consideration by DOE
- **The UFDC is sensitive to cost and schedule drivers and is evaluating ways to incorporate modeling and simulation coupled with uncertainty quantification to help bound how much testing may be needed to close technical data gaps.**