SAND2013-7069C

Used Fuel Disposition Campaign

OVERVIEW

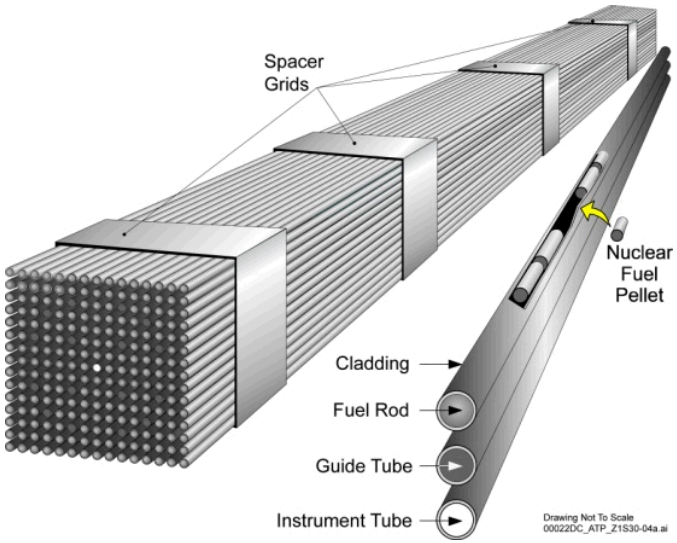
MPACT Working Group Meeting

August 28, 2012
Germantown, MD

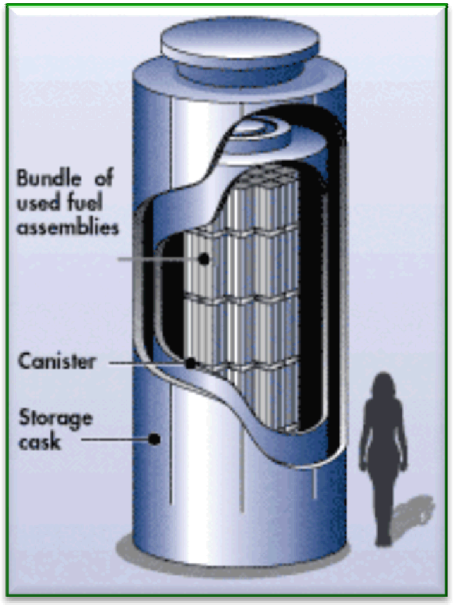
Sylvia Saltzstein
Manager: Used Fuel Storage & Transportation R&D
Sandia National Laboratories

Contents

- Overall Objectives
- Major Activities
- Collaborations



http://energy.gov/sites/prod/files/styles/



www.nrc.gov/waste/spent-fuel-storage/

www.connyankee.com/

Used Fuel Disposition R&D Campaign

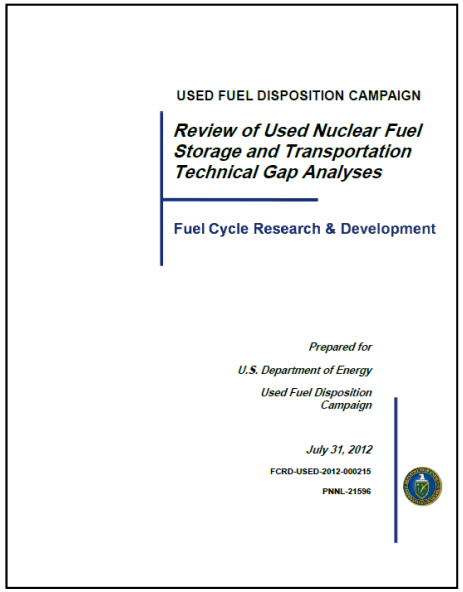
The DOE Office of Used Nuclear Fuel Disposition Research and Development and nine national laboratories participate in the DOE Office of Nuclear Energy's "Used Fuel Disposition Campaign"

Campaign Mission:

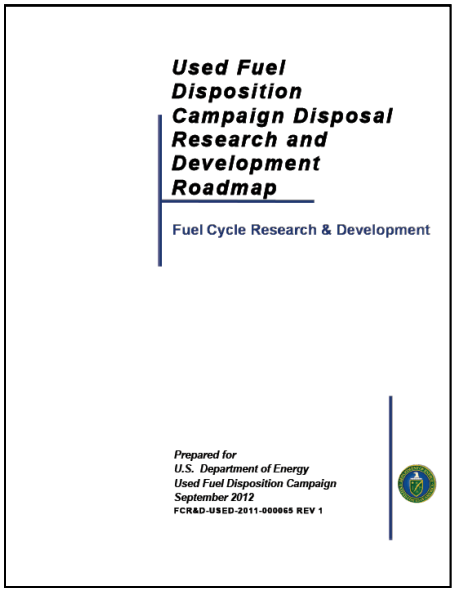
to identify alternatives and conduct scientific research and technology development to enable storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles

Disposal Research

- **DOE's Disposal R&D activities are guided by**
  - Recognition of four basic areas of R&D focus
    - *Mined repositories in salt, clay/shale, and crystalline rock*
    - *Deep borehole concepts*
  - Development of a Disposal R&D Roadmap that
    - *Identifies R&D gaps*
    - *Prioritizes them based on adequacy of existing knowledge to support current stage of the program*



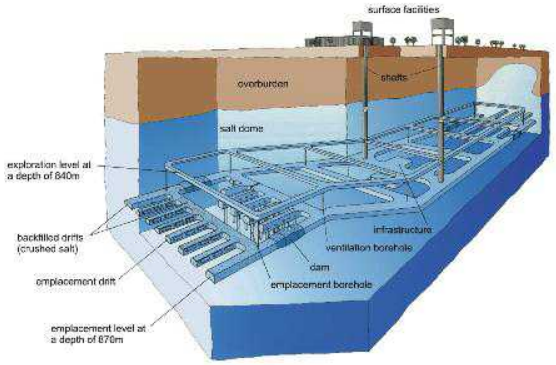
http://energy.gov/ne/downloads/basis-identification-disposal-options-research-and-development-spent

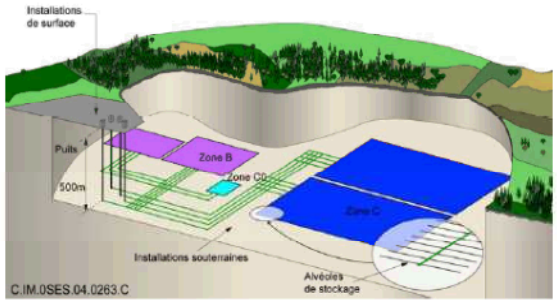


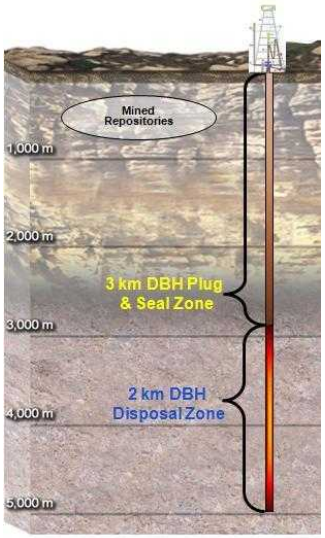
http://energy.gov/ne/downloads/used-fuel-disposition-campaign-disposal-research-and-development

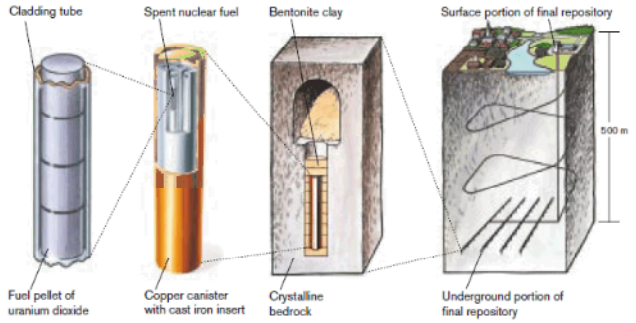
DOE's R&D Focus for UNF & HLW Disposal

- Provide a sound technical basis for multiple viable disposal options in the US
- Increase confidence in the robustness of generic disposal concepts
- Develop the science and engineering tools needed to support disposal concept implementation







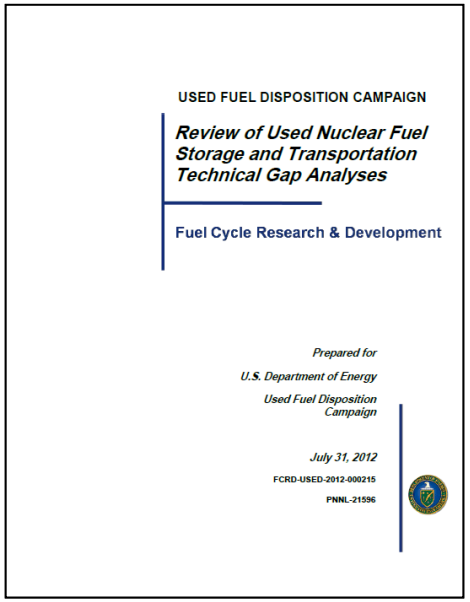


DOE's R&D Focus for Storage & Transportation

- **Prepare for extended storage and eventual large-scale transport of used nuclear fuel and high-level radioactive waste**
- **Develop the technical basis for**
  - Extended storage of used nuclear fuel
  - Fuel retrievability and transportation after extended storage
  - Transportation of high-burnup used nuclear fuel

Storage & Transportation R&D

- **DOE's Storage and Transportation R&D Activities are Guided by**
  - Detailed analysis of gaps in the existing technical bases
  - Thorough review of comparable gap analyses by others
    - *U.S. Nuclear Waste Technical Review Board*
    - *U.S. Nuclear Regulatory Commission*
    - *Electric Power Research Institute*
    - *International Atomic Energy Agency*


USED FUEL DISPOSITION CAMPAIGN

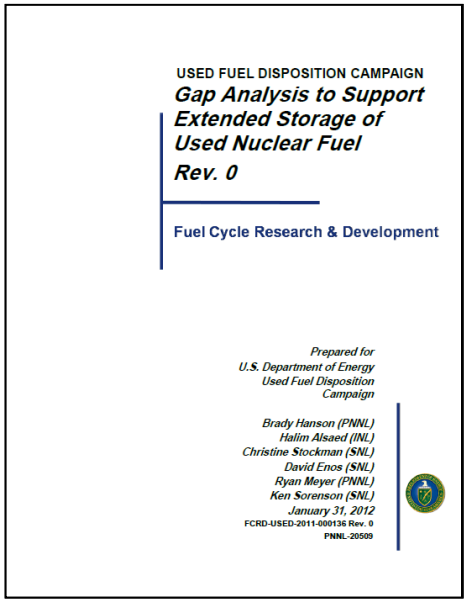
Review of Used Nuclear Fuel Storage and Transportation Technical Gap Analyses

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

July 31, 2012
FCRD-USED-2012-000215
PNNL-21596

http://energy.gov/sites/prod/files/Gap%20Analysis%20Rev%200%20Final.pdf


USED FUEL DISPOSITION CAMPAIGN

Gap Analysis to Support Extended Storage of Used Nuclear Fuel
Rev. 0

Fuel Cycle Research & Development

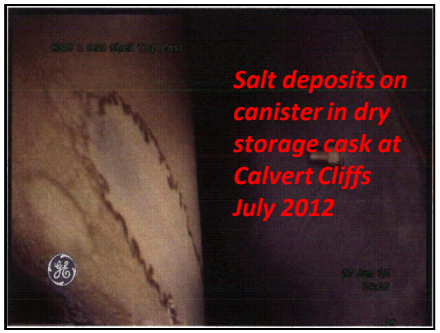
Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

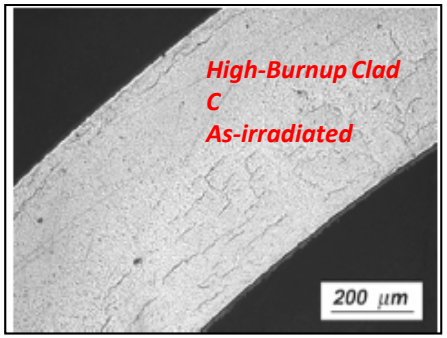
Brady Hanson (PNNL)
Halim Alsaed (INL)
Christine Stockman (SNL)
David Enos (SNL)
Ryan Meyer (PNNL)
Ken Sorenson (SNL)
January 31, 2012
FCRD-USED-2011-000136 Rev. 0
PNNL-20509

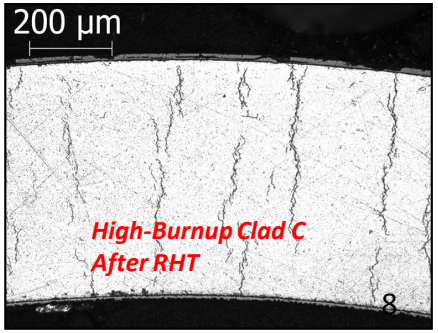
http://energy.gov/sites/prod/files/Gap%20Comparison%20Rev%200.pdf

Technical Challenges & Opportunities for Storage & Transportation Research

- **Performance of spent fuel in extended storage**
  - Aging of canisters, casks, cladding, internals
- **Performance of high-burnup fuel in storage**
- **Most reactors now generate higher-burnup fuel (up to 60 GWd/MT) than what is currently licensed for storage**
- **Higher temperatures cause hydride reorientation in clad, subsequent embrittlement**
- **Spent fuel must be transportable at the end of extended storage**
  - Retrievability
  - Criticality control
- **Opportunities: collaboration with NRC, industry, and universities**



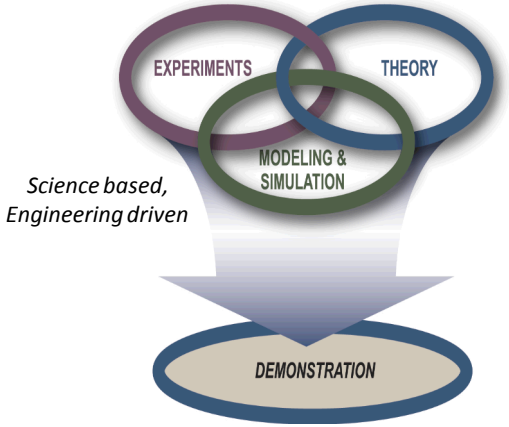




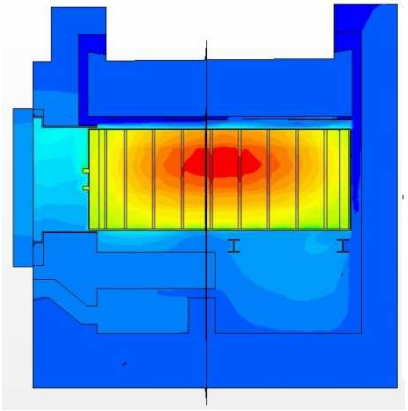
Storage & Transportation Scope

Science Based, Engineering Driven

- **From Å to M**
- **Combining theory, experiments and predictive models. Verifying with the large scale demonstration.**



UFD Telecon, April 12, 2012
Billone, Liu; Argonne

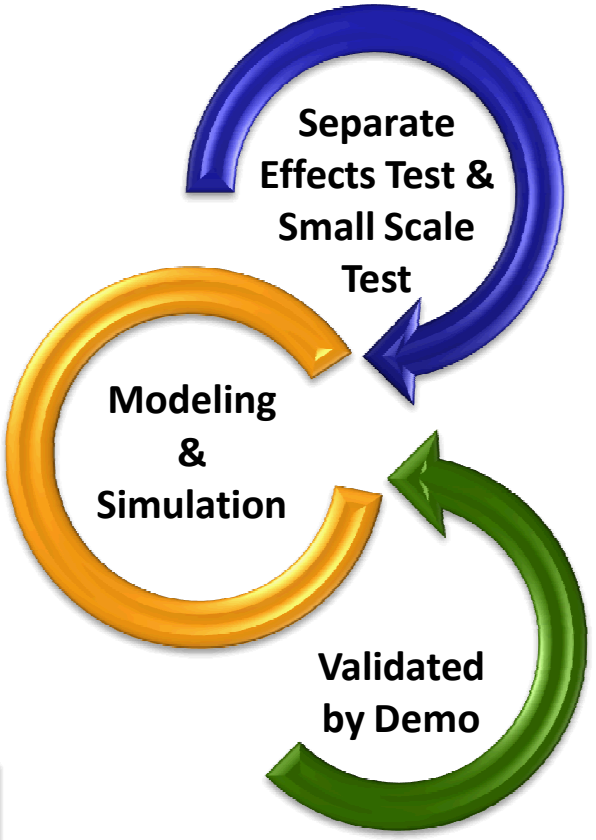


UFD Telecon, April 12, 2012
Wagner, Adkins; ORNL

'Jones 2010.ppt',
Calvert Cliffs Dry Fuel Storage and Industry Lessons Learned

Storage & Transportation Control Accounts

- **Five Control Accounts are designed to define the work to address the objectives**
  - Experiments
  - Engineering Analysis
  - Transportation
  - Field Demonstration
  - Security



All work is prioritized according to the 2012 UNF S&T Data Gap Prioritization. FCRD-USED-2012-000109.

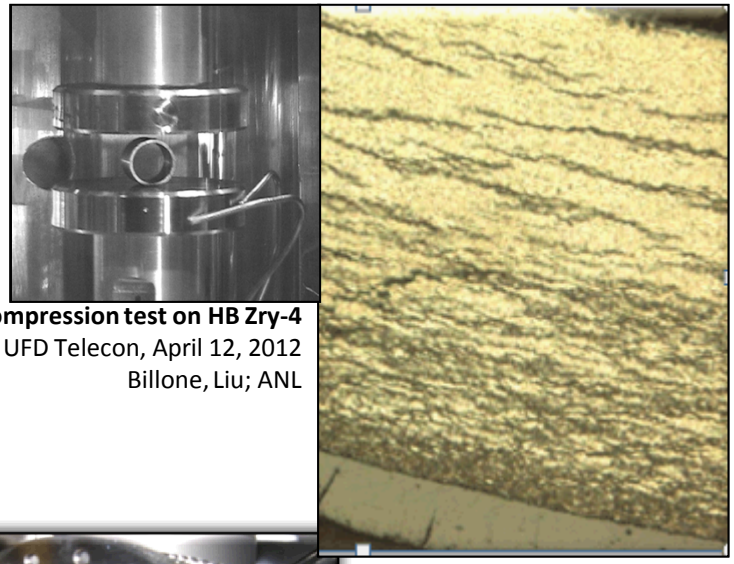
ST Experiments

USED FUEL DISPOSITION

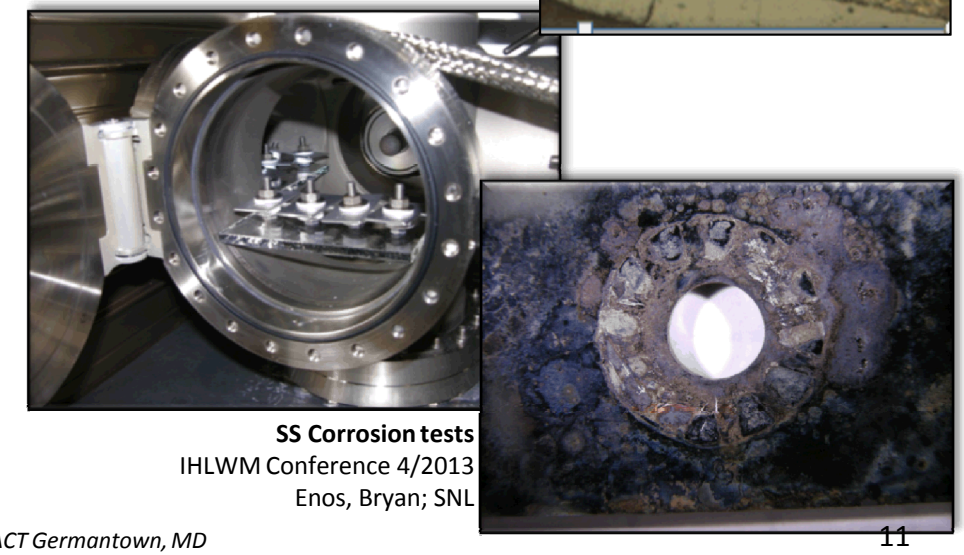
Obtain data to better understand material degradation effects on cladding and canister materials during long-term storage conditions.

IMPACT – To Understand:

1. **How do hydrides form in fuel as it ages?**
2. **What is the chemistry around a dry storage cask?**
3. **How can we store fuel so it ages well?**



Ring compression test on HB Zry-4
UFD Telecon, April 12, 2012
Billone, Liu; ANL



SS Corrosion tests
IHLWM Conference 4/2013
Enos, Bryan; SNL

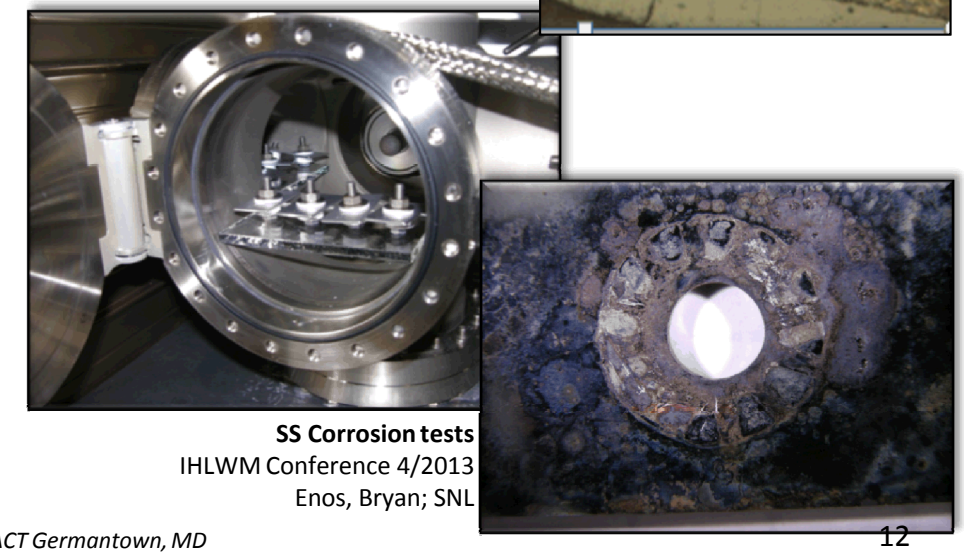
ST Experiments

Obtain data to better understand material degradation effects on cladding and canister materials during long-term storage conditions.

CURRENT WORK

- **Conduct ring compression and DBTT tests on PWR high burnup cladding**
- **Conduct hydrogen doping and irradiation in HFIR**
- **Conduct hydrogen doping/ distribution tests with thermal gradients across cladding**
- **Conduct SS canister corrosion testing**

Ring compression test on HB Zry-4
UFD Telecon, April 12, 2012
Billone, Liu; ANL



SS Corrosion tests
IHLWM Conference 4/2013
Enos, Bryan; SNL

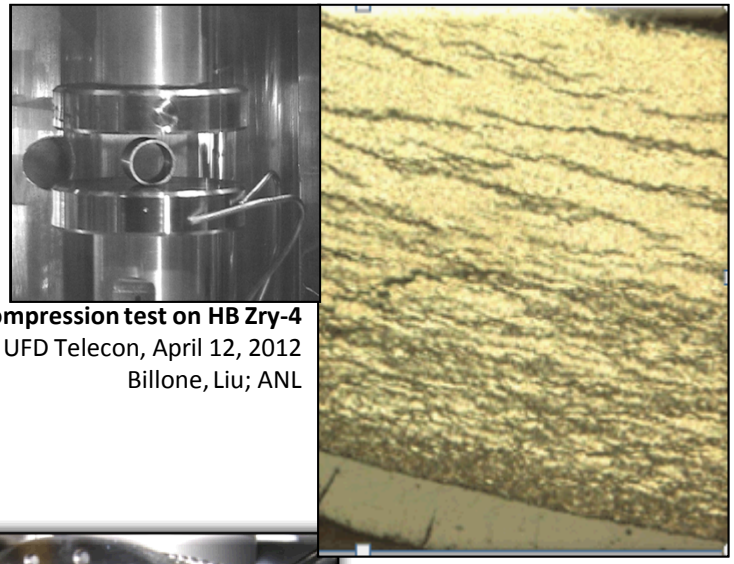
ST Experiments

USED FUEL DISPOSITION

Obtain data to better understand material degradation effects on cladding and canister materials during long-term storage conditions.

FY14

- **Materials properties of cladding**
  - Hydride effects
  - Radiation damage annealing
  - Effects of numerous wetting and drying cycles
- **Corrosion and SSC of SS canisters**
- **On-site environmental sampling**
- **Monitoring and Instrumentation**
- **Aging management plans**
- **BWR and PWR Ring Compression Test**



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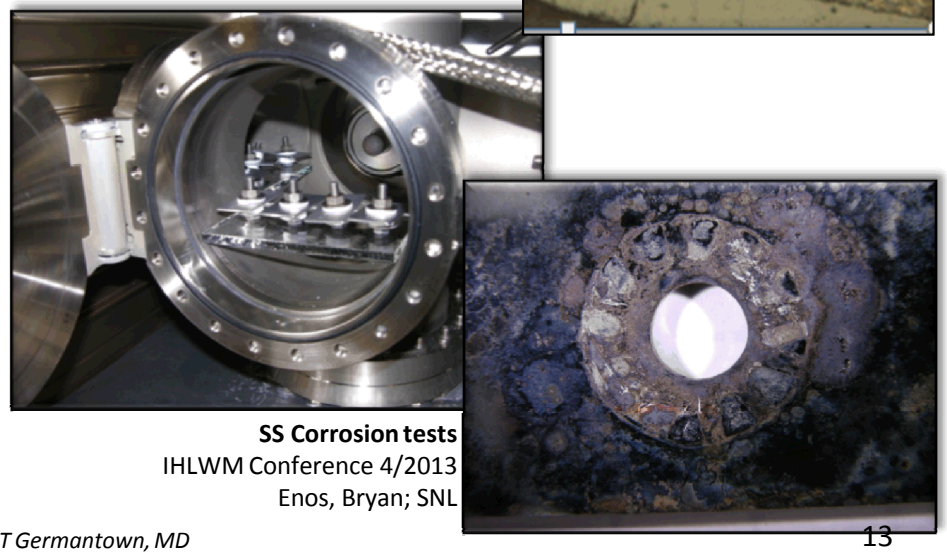


SS Corrosion tests
IHLWM Conference 4/2013
Enos, Bryan; SNL

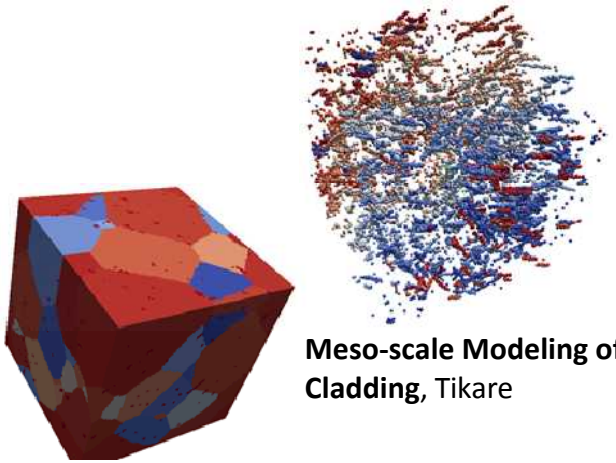
Engineering Analysis

Develop models that will predict behavior during long-term storage and transportation conditions.

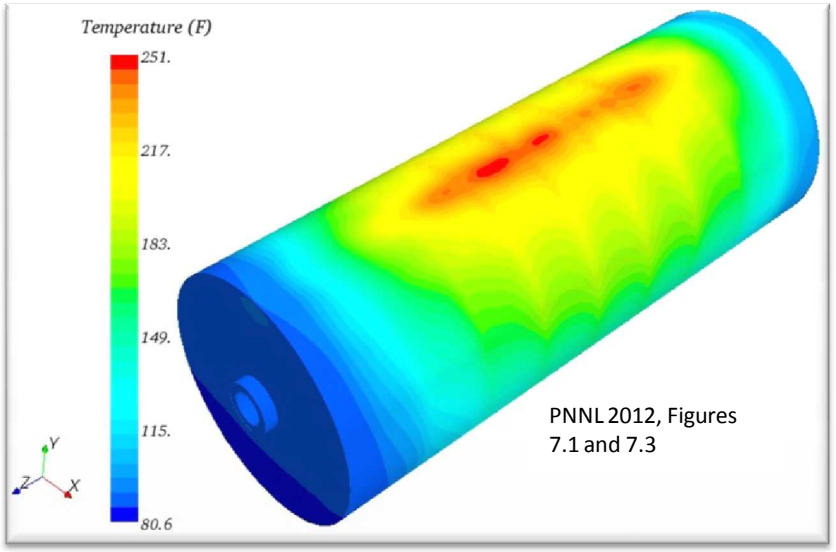
IMPACT – To Understand And Be Able To Predict:

1. **If hydrides form in a way that would embrittle fuel as it sits in dry storage.**
2. **If high-burnup fuel can withstand normal transport on rail and truck.**
3. **How dry storage canisters cool over time.**

- **This testing addresses identified high priority gaps in**
  - Thermal profiles
  - Cladding integrity
  - Cladding differences



Meso-scale Modeling of Cladding, Tikare



Thermal Profile of Storage Canister

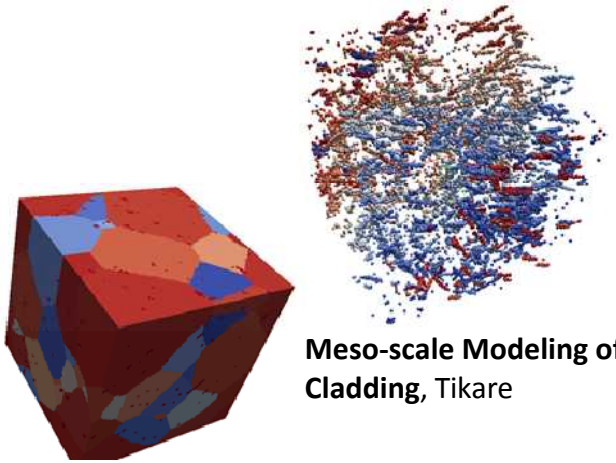
Engineering Analysis

USED FUEL DISPOSITION

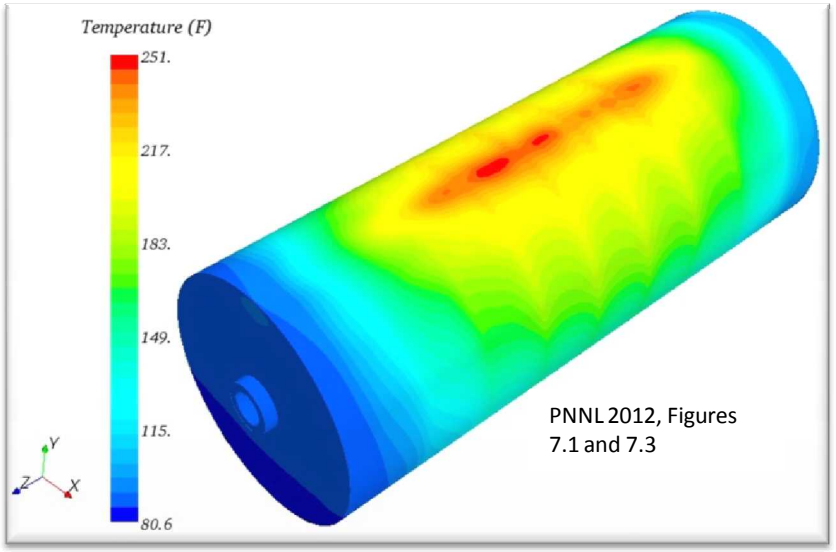
Develop models that will predict behavior during long-term storage and transportation conditions.

CURRENT WORK

- **Develop methodology to estimate used fuel cladding hydride re-orientation during long term dry storage**
- **Understand strains on fuel rods during normal truck transport.**
- **Conduct thermal profile analyses on dry storage canister systems**



Meso-scale Modeling of Cladding, Tikare



Thermal Profile of Storage Canister

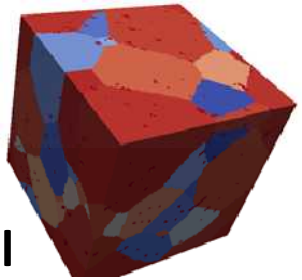
Engineering Analysis

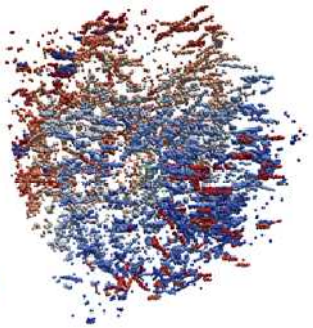
USED FUEL DISPOSITION

Develop models that will predict behavior during long-term storage and transportation conditions.

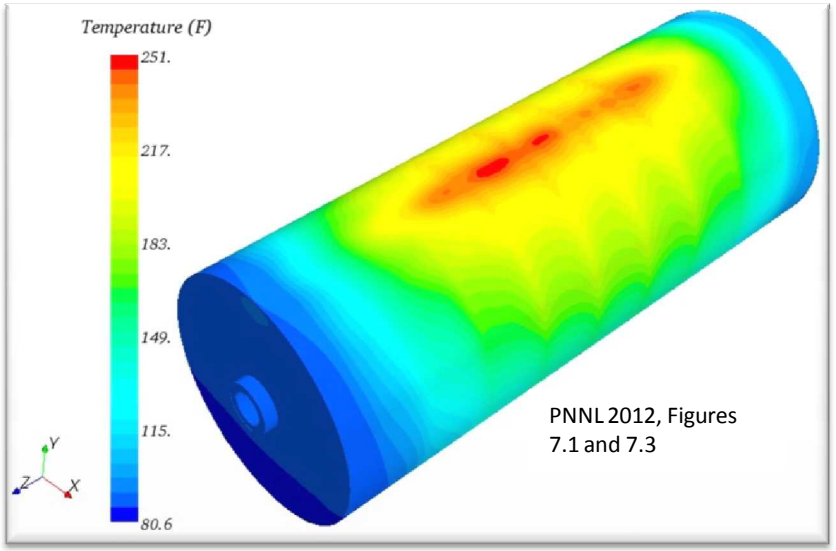
FY14

- **Benchmark basic mechanical-microstructure hydride model on Zircaloy-4 to ANL ring compression test data and incorporate into Moose-Bison Model.**
- **Understand strains on fuel rods during normal truck and rail transport.**
- **Continue thermal profile modeling of storage systems.**
- **Initiate Uncertainty Quantification (UQ) methodology development to focus testing and prioritize high and medium ranked gaps.**





Meso-scale Modeling of Cladding, Tikare



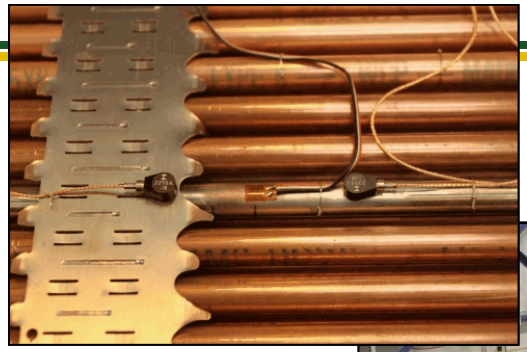
Thermal Profile of Storage Canister

Transportation

Demonstrate the transportability of high burn up used fuel.

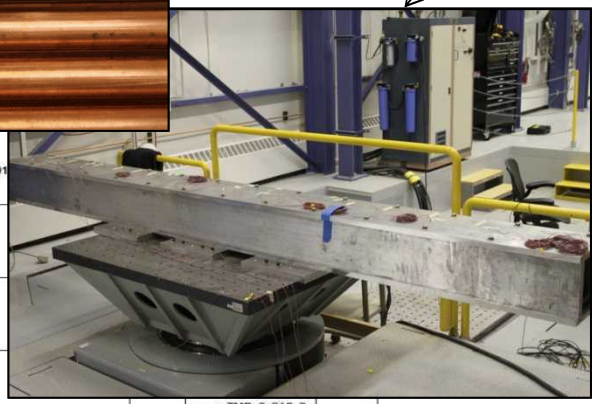
IMPACT

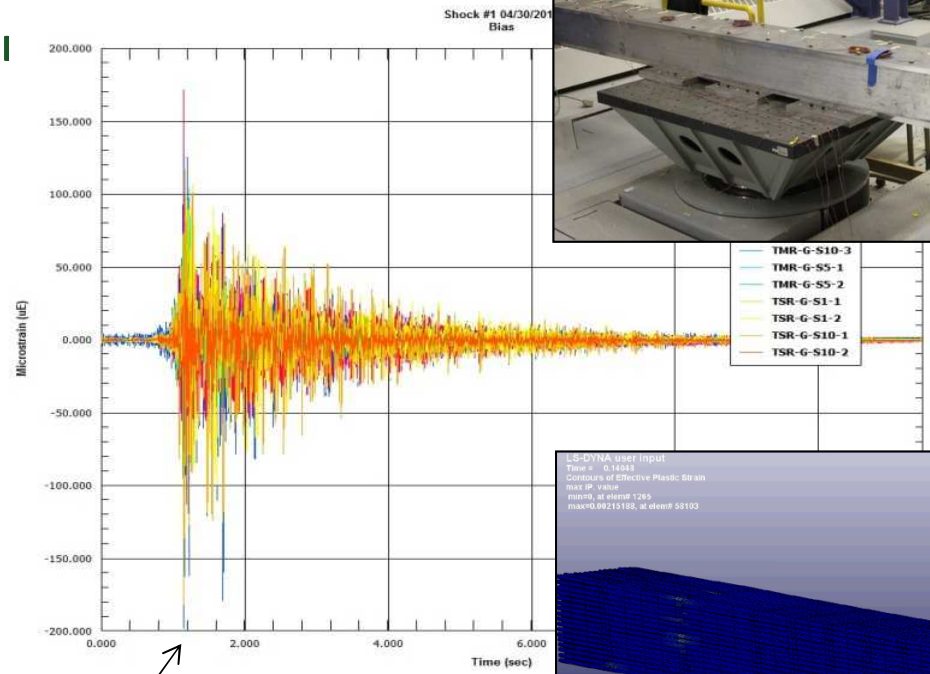
Understand if high-burnup fuel can withstand normal conditions of truck transpo



Instrumented Assembly

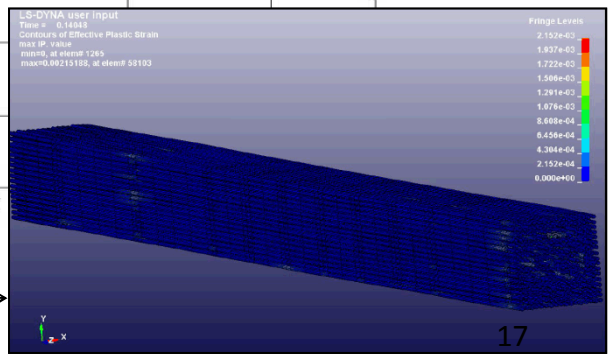
Shaker Test





Data Acquisition

Analysis

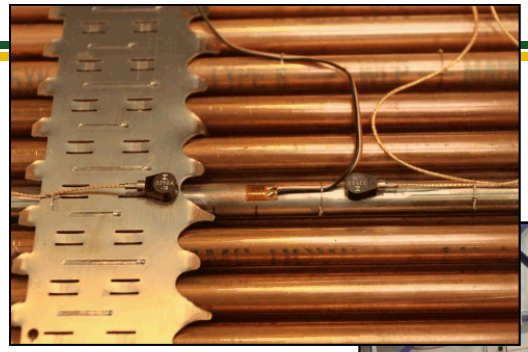


Transportation

Demonstrate the transportability of high burn up used fuel.

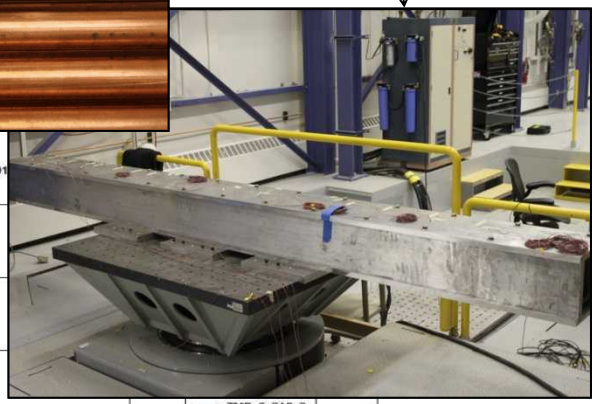
CURRENT WORK

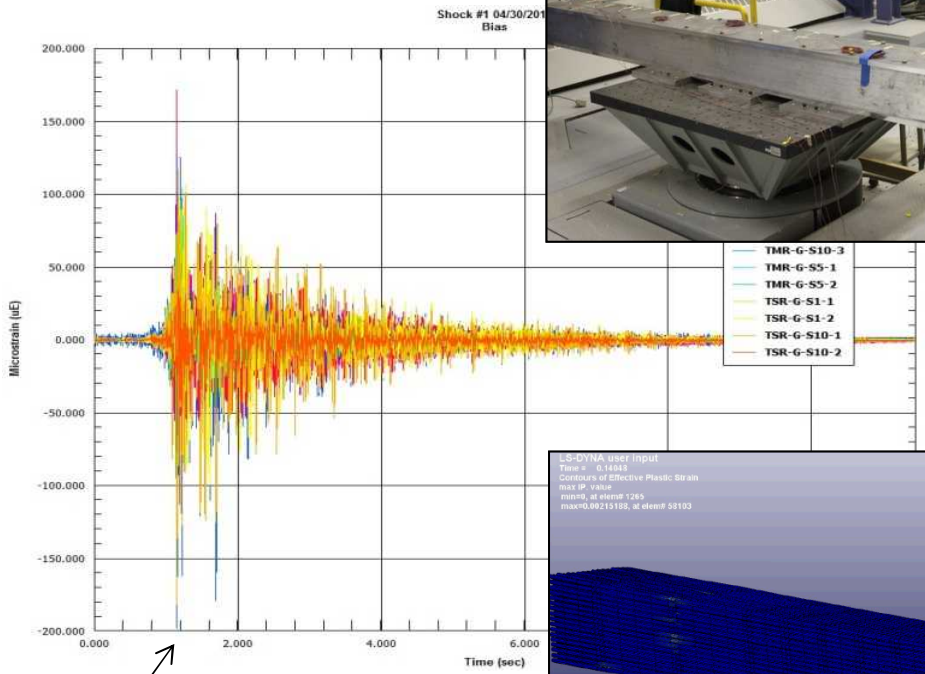
- **Conduct shock/vibration tests on a surrogate PWR assembly for truck normal conditions of transport**
- **Analyze fuel rod response to accelerometer and strain gauge data**



Instrumentation

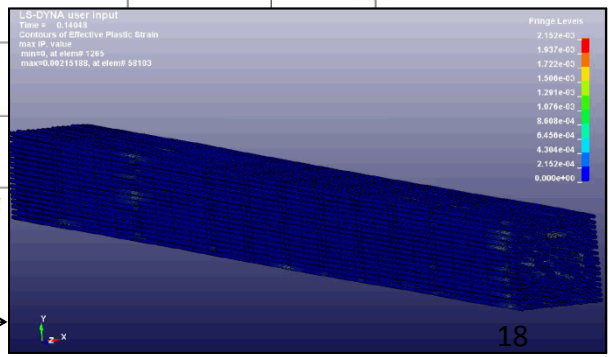
Test





Data Acquisition

Analysis

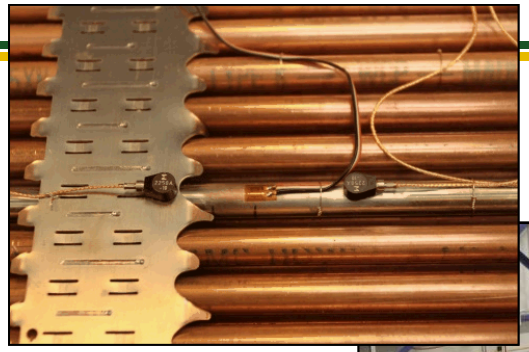


Transportation

Demonstrate the transportability of high burn up used fuel.

FY14

- Complete analyses of truck shock/vibration data
- Duplicate shock/vibration test for rail data.
- Collaborate with industry to ship an instrumented surrogate "dummy" PWR assembly to SNL to conduct a shock/vibration test using the vibration/ shock response spectra obtained from the transport.



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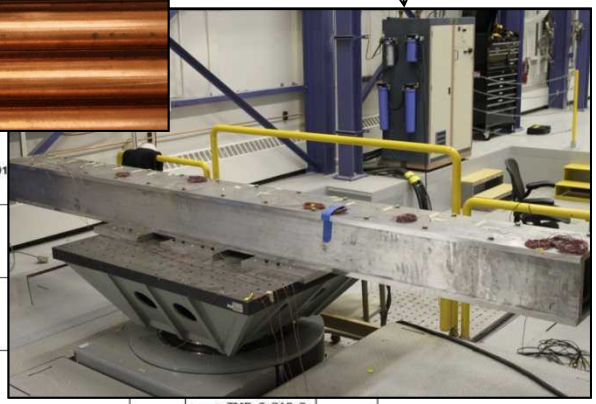

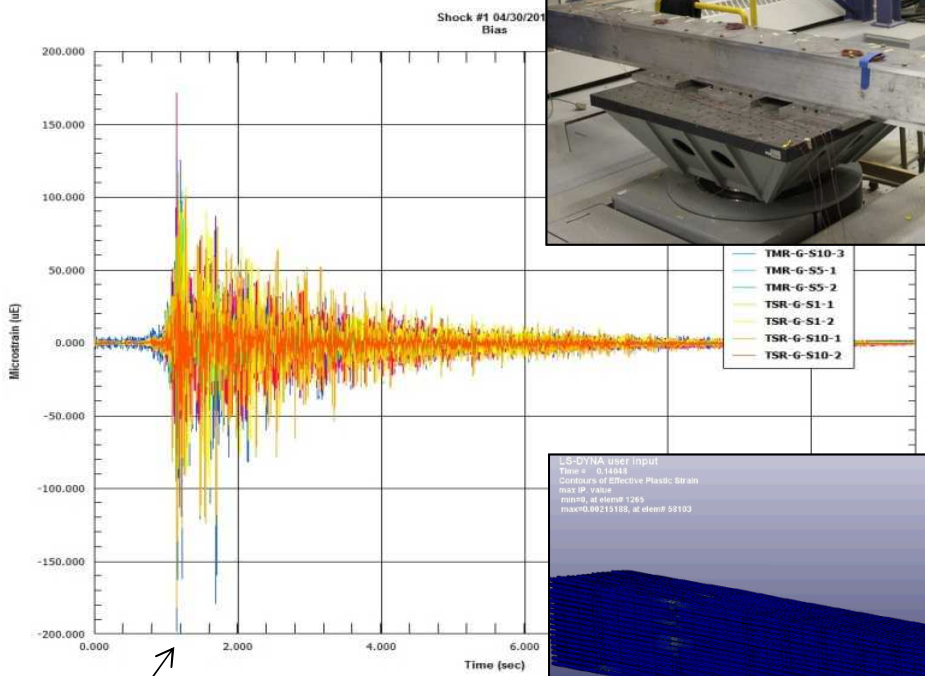

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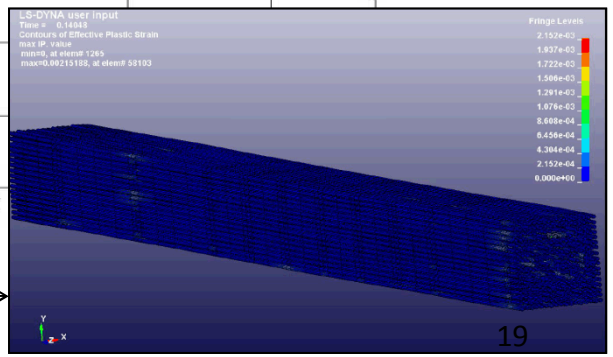
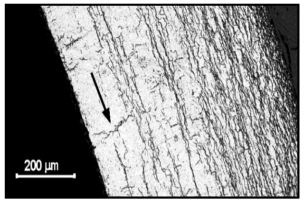


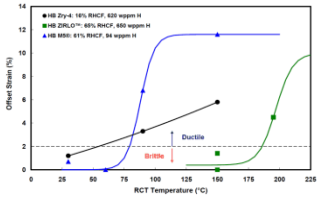
Making a Case for Transport of High Burnup Fuel

USED FUEL DISPOSITION

Experimental

Material properties
Benchmark data

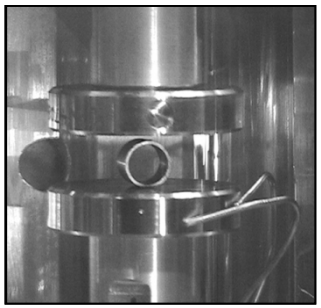




Clad morphology ⟷ ***Clad properties:***

- Hydrogen
  - Concentration
  - Distribution
  - Orientation
- Oxidation
- Pellet/clad interaction

σ_{ys} = *yield stress*
σ_{ult} = *ultimate stress*
K_{Ic} = *fracture toughness*
E = *elastic modulus*
ϵ_{ult} = *ultimate strain*



Instron 8511 used for Ring Compression Tests

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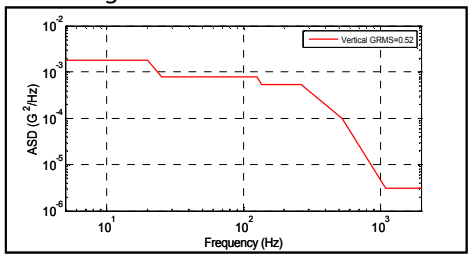
Transportation

- Realistic configurations
- Realistic loads
- Regulatory alignment

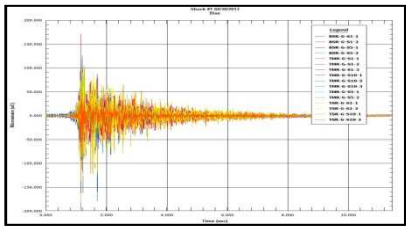
Loads:

- *Shock/vibrations loads representing normal conditions of transport*
- *g = accelerations*



Response:

- *g and ϵ on individual rods*

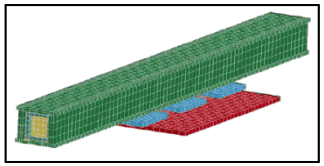


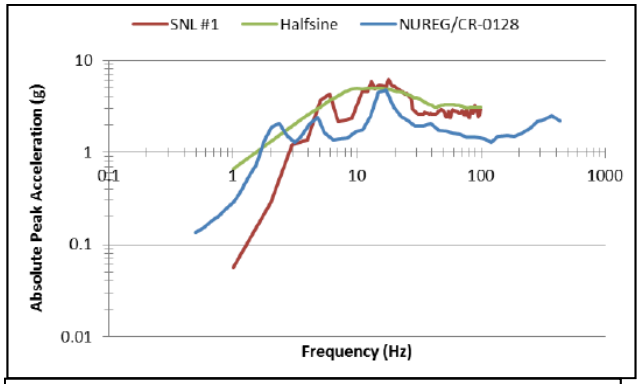
+

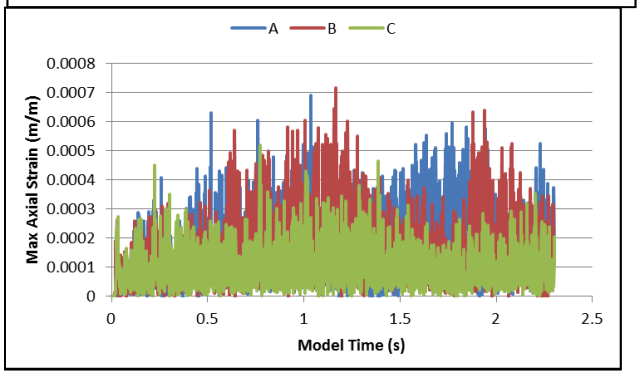
Analysis

$\sigma < \sigma_{ys}$?

$K_I < K_{Ic}$?







ST Field Demonstration

USED FUEL DISPOSITION

Monitor and inspect a cask of High-Burnup fuel in dry storage for years to get data on the behavior as it ages.

CURRENT WORK

- Support the DOE in the reviewing the Test Plan
- Collaborate with industry to develop monitoring and inspection technologies that will acquire data for many years.
- Work with industry to test fuel rods as they start the test, so we collect time zero material properties, and get validation data to compliment the R&D program

IMPACT

1. Obtain real-time data on high-burnup fuel as it begins dry storage and as it ages for years in dry storage.

FY14

- Support the planning process for fielding the demo

Goals of the Cask R&D Project

- **The near-term activities focus on experimental and analytical work that can be conducted immediately, without any modification to existing facilities.**
- **The long-term activities will focus on an actual research and development (R&D) program for the inspection and monitoring of spent fuel in storage over a longer period of time.**
- **The goals for such R&D include the following:**
  - *Benchmarking the predictive models and empirical conclusions that will be developed from short-term laboratory testing for aging of dry storage cask system components; and*
  - *Building confidence in the ability to predict the performance of these systems over* extended time periods.

High Burnup Dry Storage R&D Project

- **Involves:**
  - Loading a commercial storage cask with high burn-up fuel in a utility storage pool
    - *Well understood fuel*
    - *Cask outfitted with additional instrumentation for monitoring*
  - Drying of the cask contents using prototypic process
  - Cask will be housed at the utility's dry cask storage site
    - *Continuously monitored and externally inspected until the first internal inspection at ~10 years*
  - A second cask could be loaded ~5 years following the first with a focus on additional scientific data on fuel behavior
- **The issue of where the cask will be opened will be decided at a later date.**

USED FUEL DISPOSITION Contract Was Awarded to the EPRI Team

- **The EPRI Team consists of:**

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Dominion

- ***Surrey Plant***
- ***North Anna Plant***

AREVA Federal Services
AREVA Transnuclear
AREVA Fuels

EPRI Contract Summary

Proposal Item	EPRI Proposal
PWR Reactor	Surrey or North Anna
Cladding Types	Zircaloy 4 – all vendors Zirlo, - Westinghouse M5 - AREVA
Fuel Types	Numerous Assemblies > 50 GWD/MTU
Utility Infrastructure	Has all infrastructure & equipment needed to handle the cask
Cask	Trans-nuclear 32 (bolted lid metal cask) Part 71& 72 Certified
Loading reactor	Surrey or North Anna
Proposed ISFSI	Surrey or North Anna
Total Cost	$19,799,547
Cost Share	20% - ($16.8 million from DOE)

Cask Demo FY 14 Activities

- Complete Test Plan
- Continue engineering to modify the cask lid
- Begin modification of Site-Specific License *(Dominion)*
- Extract sister pins from assemblies
- Identify sister pins to be tested
- Load truck cask with sister pins
- Ship sister pins to National Lab
- Begin interactions with the NRC *(NRC Payments)*
- Instrumentation design and long lead procurement
- Perform measurements on loaded casks

Security

CURRENT WORK

- Assess current regulatory rule-making developments
- Assess security implications related to early shipments of used fuel

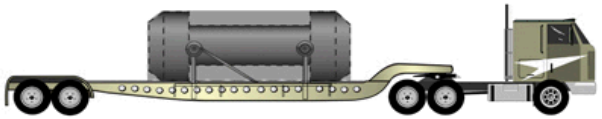
www.connyankee.com

IMPACT

1. Important security implications arising from long-term storage and transportation will be assessed

FY14

- Continue assessment of the regulatory rule-making process and changes being considered for UNF storage and transportation, especially as it relates to de-inventorying orphaned sites



Waste Forms Study

Questions to Answer:

- Is a "one-size-fits–all" repository a good strategic option for disposal?
- Do different waste types and forms perform differently enough in different disposal concepts that they warrant different treatment?
- Do some disposal concepts perform significantly better with or without specific waste types or forms?

Due end of September

Stay Tuned!!!

Collaborations

External collaborations are an important part of this program.

One important focus for external collaborations is through the Electric Power Research Institute Extended Storage Collaboration Program (EPRI/ESCP)

Vision: Provide the technical bases to ensure safe, long-term used fuel storage and future transportability.

Objectives:

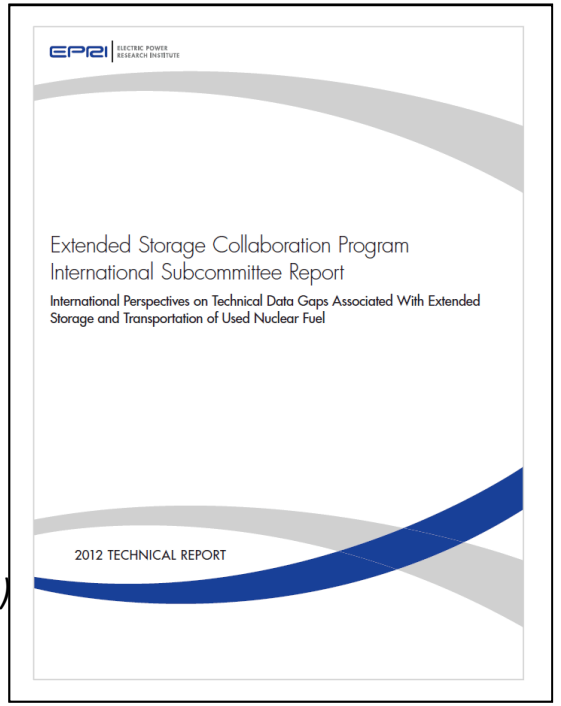
- **Identify what we already know**
- **Identify the open items for even longer storage (gap analysis)**
- **Suggestions for what needs to be done (and how, if possible)**
- **Form standing groups to continue pursuing additional, appropriate R&D**

Standing Subcommittees:

- Fuel/Internals
- Demonstration
- Marine Environments
- Concrete
- Nondestructive Examination
- International

Participants:

- *Industry (EPRI/NEI/fuel & cask vendors/utilities)*
- *U.S. Nuclear Regulatory Commission*
- *U.S. Department of Energy (DOE)*
- *DOE laboratories*
- *Universities*
- *International organizations*



Recent deliverable: International Data Gap Report

http://my.epri.com/portal/server.pt?Product_id=000000000001026481

Conclusions

DOE/NE is supporting development of the technical basis for certification of very long term storage of used fuel and subsequent transportation. Programmatically, this includes...

- **Development of a plan to support experimental data gathering to address gaps in the existing data base**
- **Conducting experiments to gather needed data**
- **Working with the NRC to properly integrate data needs perceived by both the regulator and industry**
- **Working closely with industry**
- **Working closely with our international partners, and development of the technical basis documents**

Concluded ...thank you

Used Fuel Disposition Campaign

OVERVIEW

MPACT Working Group Meeting

August 28, 2012
Germantown, MD

Sylvia Saltzstein
Manager: Used Fuel Storage & Transportation R&D
Sandia National Laboratories