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Developing the Technical Basis for Extended Long Term Storage and Subsequent Transportation of Used Nuclear Fuel

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Fundamental Plutonium Properties

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Contents

- The Issue
- Status of dry storage in the United States
- Program to develop the technical basis for extended storage
- Discussion of data gaps
- Collaboration with industry and regulators
- Conclusions

Policy Decision → Issues → Consequences

Policy

The decision to cancel the Yucca Mountain Repository licensing process will mean that the United States will need to store used fuel for the foreseeable future (>100 yrs).

Yucca Mountain Repository Site

Issues

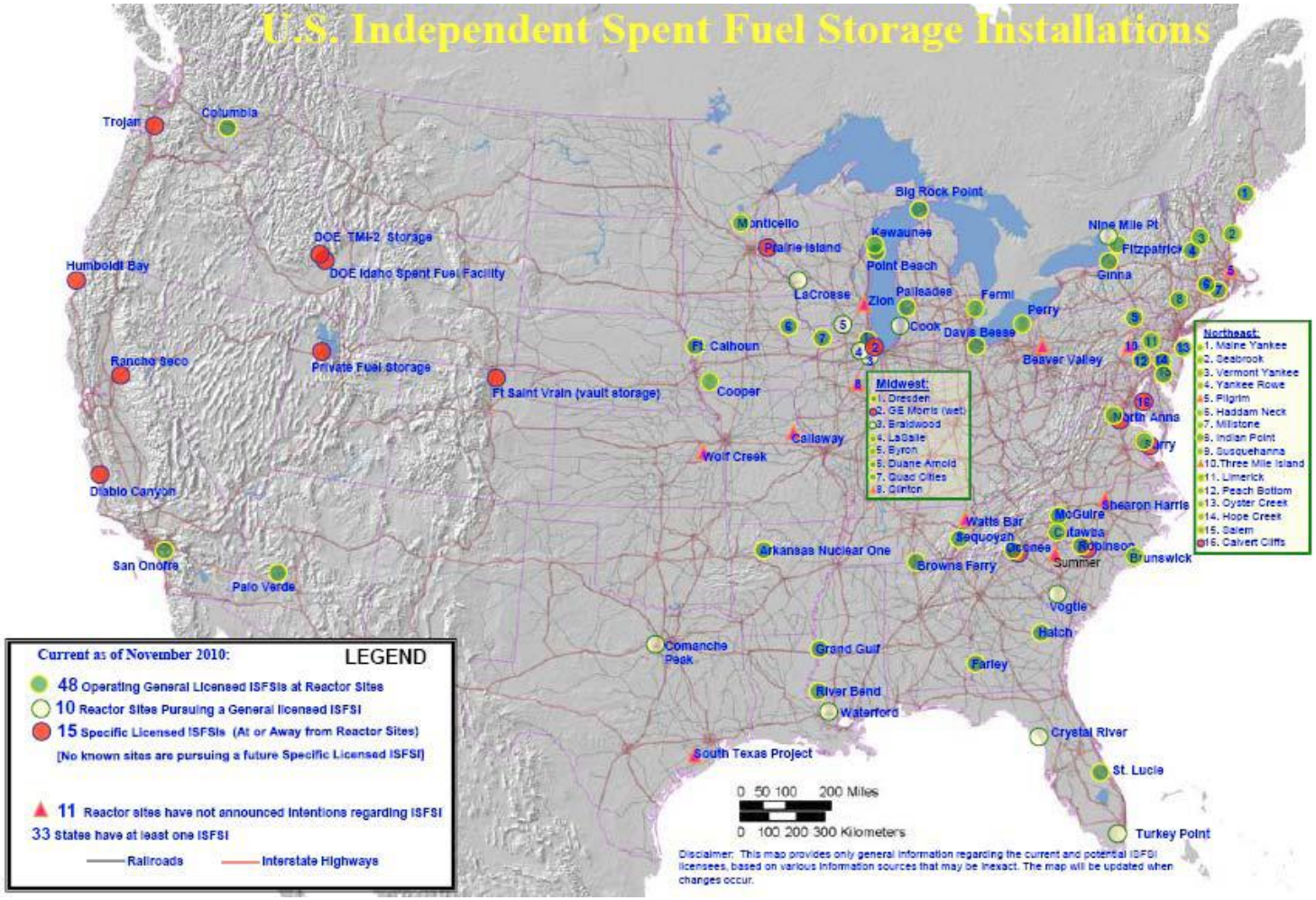
- **Long term dry storage of used fuel has been licensed only up to 60 yrs**
- **Questions regarding transport of used fuel after long term storage**
- **Questions regarding storage and transportation of high burnup fuel (>45 GWD/MTU)**

Consequences

- **A technical basis needs to be developed to justify licensing used fuel storage beyond 80 years**
- **A technical basis needs to be developed to justify licensing the transport of used fuel after long-term storage**
- **A technical basis needs to be developed to justify licensing the transport of high burnup fuel**

Extended On-Site Storage

Status of Used Fuel Storage in the U.S



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- ***63 storage sites licensed in the U.S.***
- ***~65,000 MTU in storage***
  - ***~15,000 MTU dry storage***
  - ***~50, 000 MTU wet storage***
- ***U.S. fleet discharges ~2000 MTU/yr***

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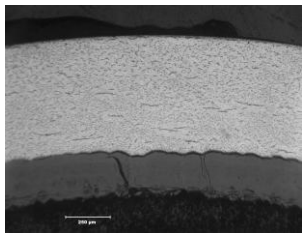
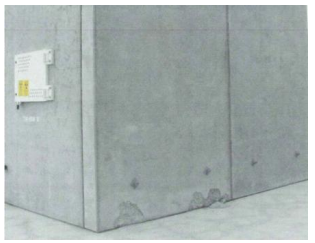
DOE Program to Develop Technical Basis for Extended Storage and Subsequent Transportation

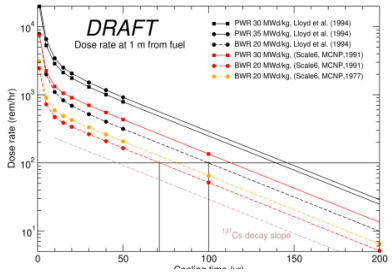
- **Storage R&D Investigations**
  - Data gap analyses
  - Plan to address gaps
  - Development of technical basis

Focus of this presentation

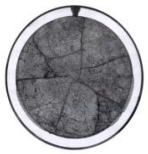


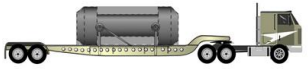


- **Security**
  - Regulatory assessment
  - Identify issues peculiar to long-term storage
  - Evaluate vulnerability analysis methodology improvements



- **Transportation**
  - High burnup fuels
  - Transportation of all fuels after storage

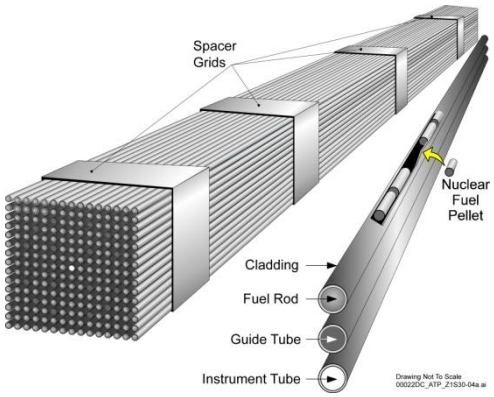




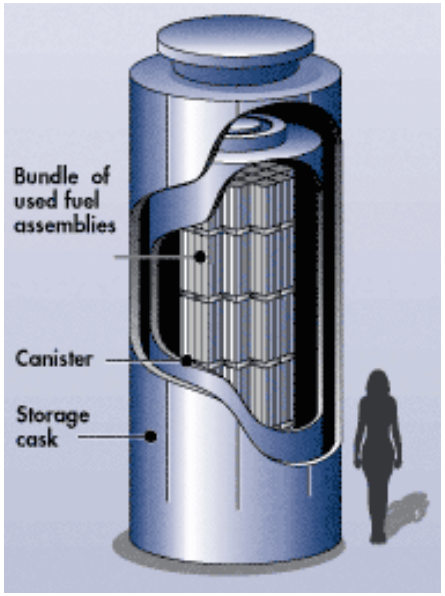
- **Conceptual Evaluation**
  - Evaluate scenarios for accomplishing development of technical basis
  - Develop a systems framework for decision-making

Storage Structures, Systems & Components (SSCs) that need to be assessed for extended storage

I. Fuel
- I. Fuel/Pellet
- II. Cladding
- III. Assembly hardware



II. Cask
- I. Internals (baskets, neutron poisons)
- II. Container (canister, welds, seals, bolts)
- III. Neutron shields
- IV. Overpack/Storage module

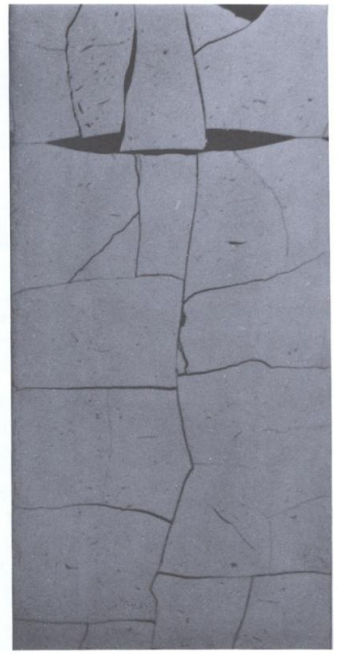


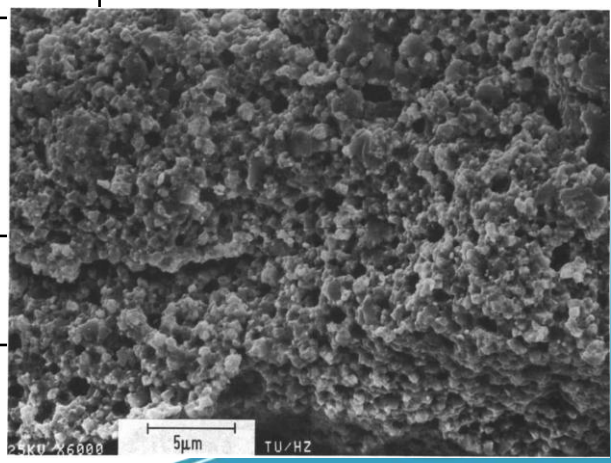
III. ISFSI
- I. Pad
- II. Rebar
- III. Physical Protection

IV. Monitoring Systems
- I. Remote inspection
- II. In-package sensors
- III. Security

What are the data gaps?
Fuel

Stressor*	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal and Mechanical	Fuel Fragmentation	Yes	Yes	Low
	Restructuring/ Swelling	Yes	Yes	Low
Chemical	Fission product attack on cladding	Yes	Yes	Low
	Fuel oxidation	Yes	Yes	Low

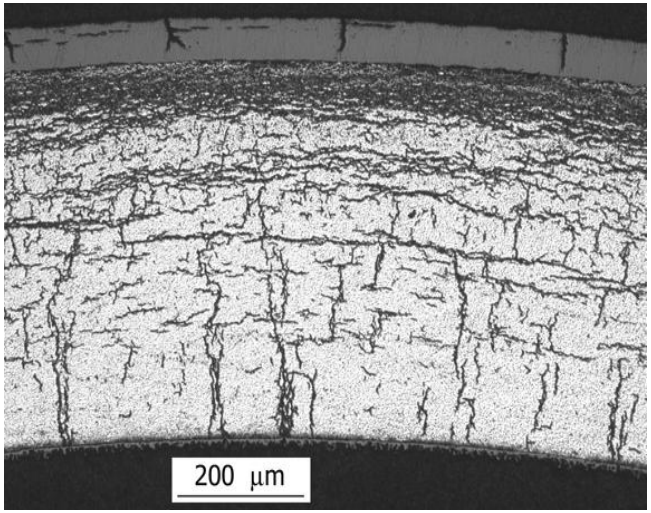




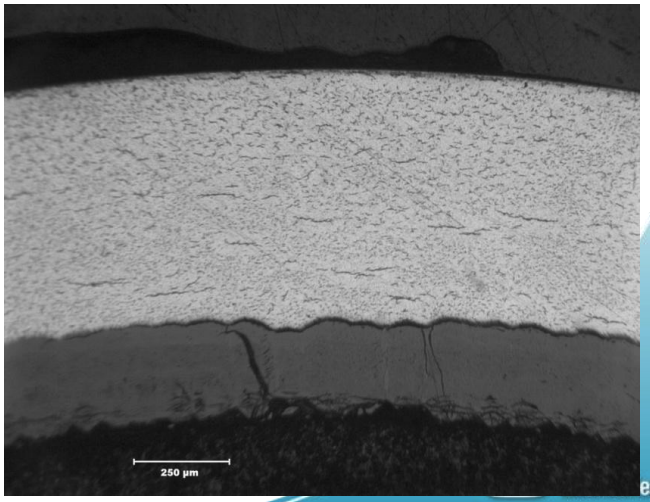
*Stressor: mechanism causing degradation

What are the data gaps?
Cladding

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal	Annealing of radiation damage	Yes	Yes	**Medium**
	Metal fatigue caused by temperature fluctuations	Yes	Yes	Low
	Phase change	No	Yes	Low
Chemical	Emissivity changes	No	Yes	Low
	H_2 effects: Embrittlement and reorientation	Yes	Yes	**High**
	H_2 effects: Delayed hydride cracking	Yes	Yes	**Medium**
	Oxidation	Yes	Yes	**Medium**
	Wet Corrosion:	No	Yes	Low
Mechanical	Creep	Yes	Yes	**Medium**



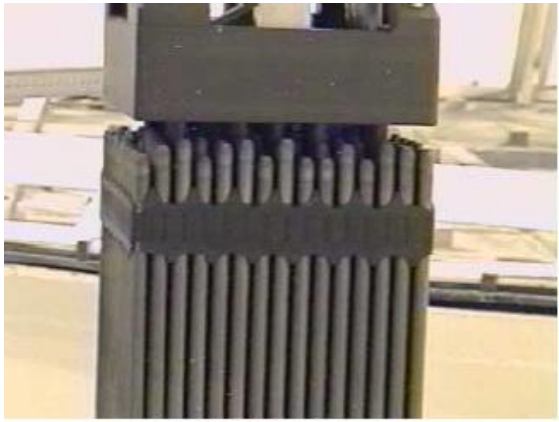
ANL Hydride and Oxidation Tests



What are the data gaps?
Assembly Hardware & Fuel Baskets

Assembly Hardware

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal and Mechanical	Creep	Yes	Yes	Low
	Metal fatigue caused by temperature fluctuations	Yes	Yes	Low
Chemical	Corrosion and stress corrosion cracking	Yes	Yes	**Medium**
	Hydriding effects	Yes	Yes	Low



Upper grid spacer and differing fuel rod growth from INL test

Fuel Baskets

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal and Mechanical	Creep	Yes	Yes	Low
	Metal fatigue caused by temperature fluctuations	Yes	Yes	Low
Chemical	Corrosion	Yes	Yes	Low

Top weld crack in fuel basket from 15-yr demo at INL

What are the data gaps?
Neutron Poisons and Shields

Neutron Poisons

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal	Thermal Aging effects	Yes	Yes	**Medium**
Thermal and Radiation	Embrittlement and cracking	Yes	Yes	**Medium**
Thermal and Mechanical	Creep	Yes	Yes	**Medium**
	Metal fatigue caused by temperature fluctuations	Yes	Yes	Low
Radiation	Poison burnup	Yes	Yes (analysis)	Low
Chemical	Corrosion (Blistering)	Yes	Yes	**Medium**

Neutron Shields

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal and Mechanical	Embrittlement, cracking, shrinkage, and decomposition	Yes	Yes	Low
Radiation	Radiation embrittlement	Yes	Yes	Low
	Poison burnup	Yes	Yes	Low
Chemical	Corrosion	Yes	Yes	Low

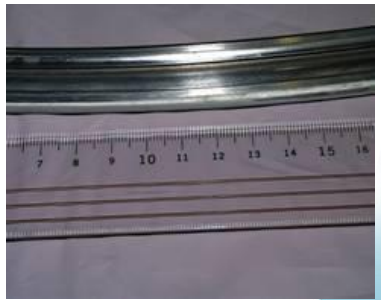
Example of BORAL blistering from EPRI

What are the data gaps?

Container (Canister/Cask-emphasis on closure systems)

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Welded Canister				
Chemical	Atmospheric Corrosion (Including Marine Environment)	Yes	Yes	**High**
	Aqueous Corrosion: general, localized (pitting, crevice), SCC, galvanic	Yes	Yes	**High**
Bolted Direct Load Casks				
Thermal and Mechanical	Embrittlement of elastomer seals	Yes	Yes	Low
	Thermo mechanical fatigue of seals and bolts	Yes	Yes	**Medium**
Radiation	Embrittlement of elastomer seals	Yes	Yes	Low
Chemical	Atmospheric Corrosion (Including Marine Environment)	Yes	Yes	**High**
	Aqueous corrosion: general, localized (pitting, crevice), SCC, galvanic	Yes	Yes	**High**

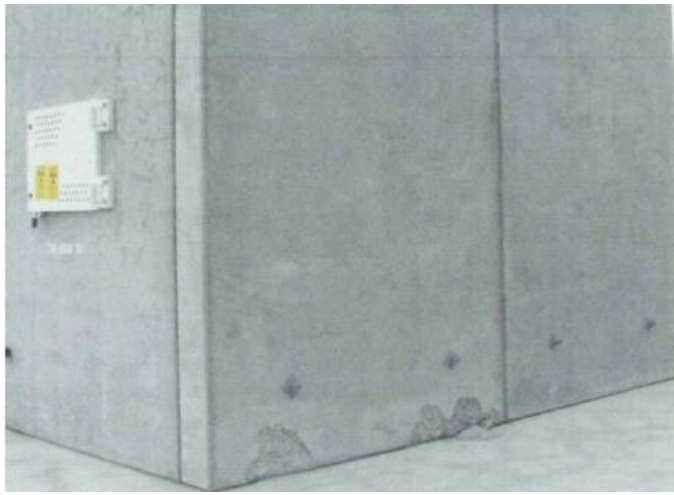
Cask bottom cover plate bolt corrosion observed in 15-yr demo at INL



White coloring on metal gasket from remaining water after 5 yr storage. Aida et al., IAEA 2010

What are the data gaps?
Overpack and Pad (Concrete)

Stressor	Degradation Mechanism	Influenced by Extended Storage or Higher Burnup	Additional Data Needed	Importance of R&D
Thermal	Dry Out	Yes	Yes	Low
	Fatigue	Yes	Yes	Low
	Freeze Thaw	Yes	Yes	**Medium**
Radiation	Aggregate Growth	Yes	Yes	Low
	Decomposition of Water	Yes	Yes	Low
Chemical	Aggregate Reaction	Yes	Yes	Low
	Calcium leaching	Yes	Yes	Low
	Chemical Attack	Yes	Yes	Low
	Corrosion of Embedded Steel	Yes	Yes	**Medium**
Mechanical	Blocked Air Flow	Yes	No	N/A
	Creep	Yes	No	N/A
	Shrinkage	No	No	N/A



Examples of concrete degradation at INL ISFSI

Collaboration with Industry and Regulators

The DOE program is making full use of all work going on in this area.

1. Technical Data Gap Analyses

The NRC is conducting its own technical data gap analysis.

- Consistent with DOE data gap analysis with some differences in priorities

The Nuclear Waste Technical Review Board has developed a similar technical data gap analysis.

- Consistent with DOE and NRC gap analysis
- Addition of emphasis on modeling

EPRI

DOE and Industry are collaborating through the Electric Power Research Institute (EPRI) in several areas.

- Providing fuels data that relates to technical data gaps
- Providing operational data/experience related to storage system performance
- Identifying fuel that may be available for test program
- Collaborating with international organizations on gap analyses

Collaboration with Industry and Regulators

2. International Collaborations

The primary interface for this work is the Electric Power Research Institute (EPRI) Extended Storage Collaboration Program (ESCP), International Subcommittee. This sub-committee is a working group made up of representatives from:

- **Germany, Hungary, Japan, Korea, Spain, United Kingdom, United States**

Objectives:

- **Share information on work being conducted by individual organizations that is relevant to all ESCP members**
- **Coordinate efforts associated with identification and prioritization of data gaps**
- **Share data/information related to on-going work associated with addressing data gaps**
- **Look for opportunities to collaborate and leverage existing programs**

Collaboration with Industry and Regulators

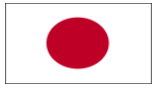
2. International Collaborations: examples of extended storage issues

Bundesanstalt fur Materialforschung und –Prufung (BAM/Germany)

- Long term behavior of metal and elastomer seals
- Long term behavior of polymers used for neutron shielding
- Optimisation of corrosion protection measures
- Transportation after long term storage
- Requirements for periodic safety inspection and aging management

Public Agency for Radioactive Waste Management (PURAM/Hungary)

- Fuel material property degradation
- Concrete structures material degradation
- Ability to transfer fuel for transportation



Central Research Institute of Electric Power Industry (CRIEPI/Japan)

- Stress corrosion cracking of canister
- Degradation of MOX fuel
- Long term storage studies

International Atomic Energy Agency (IAEA, Vienna)

- Consultancy on Dual Purpose Casks
- Consultancy on Long Term Storage

Conclusions

DOE is supporting development of the technical basis for certification of extended 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.**