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Aging Management During Spent Fuel Storage

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State Liaison Officers Conference

Spent Fuel

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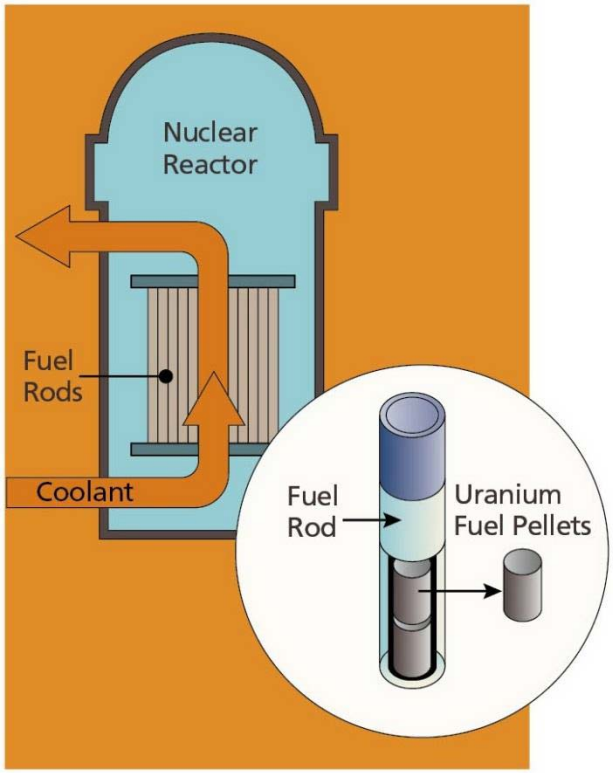
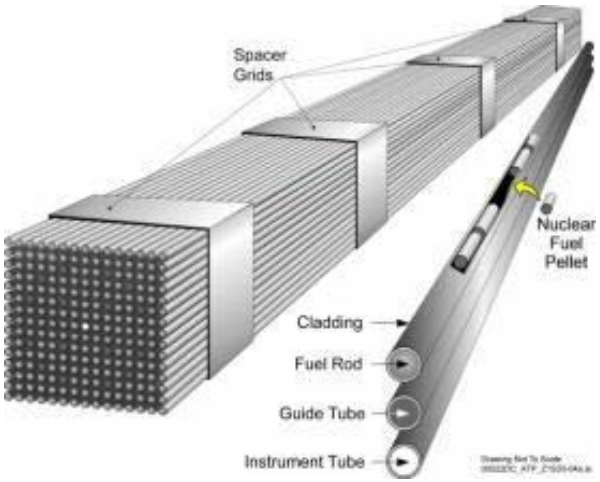


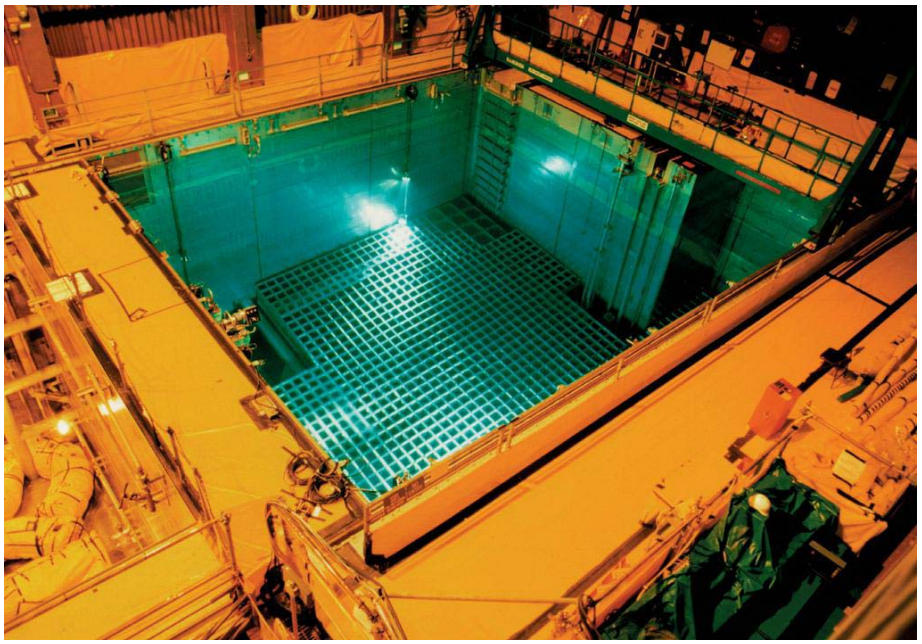
After about 5-6 years in the reactor, fuel is no longer economically useful and is removed (~ 1/3 of fuel is removed every 18-24 months)



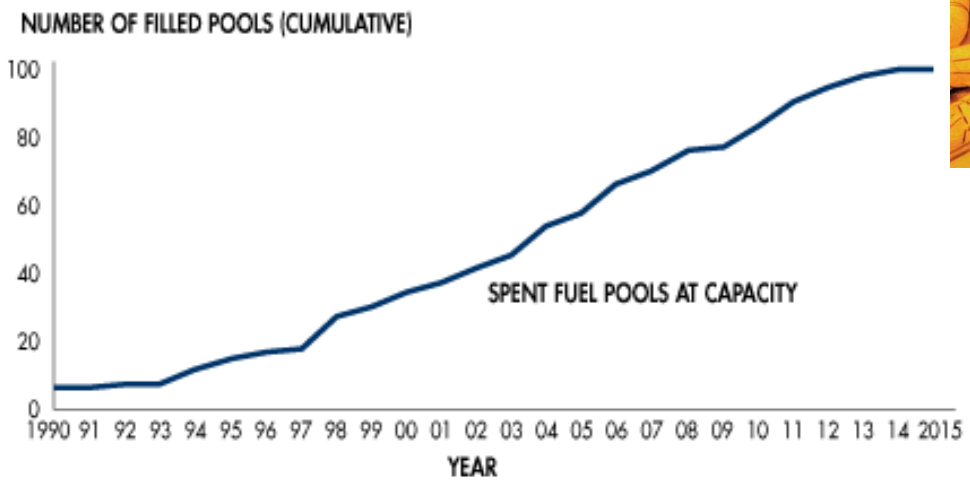
NMSS Division of Spent Fuel Management

Spent Fuel Pools

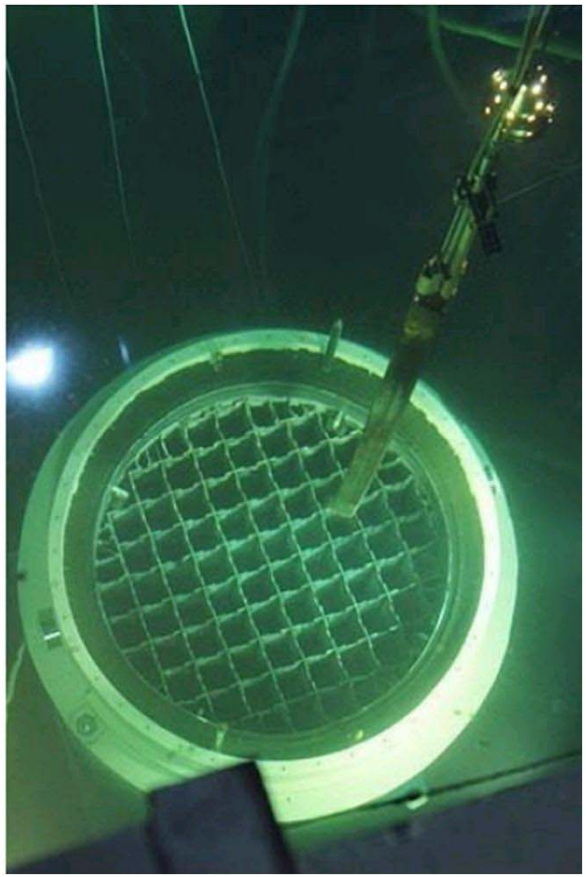
- More than 170,000 spent fuel assemblies (~ ⅔ of total) are stored in spent fuel pools at 65 reactor sites in 31 states
- Water cools the fuel and shields workers from radioactivity



San Onofre Nuclear Generating Station



Dry Storage of Spent Fuel



Operating plants must maintain full reactor core offload capability in spent fuel pools

Dry storage of spent fuel is used after the spent fuel has cooled in the pool
(typically > 5 years)

Spent Fuel Storage Regulations
10 CFR Part 72

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Review Areas

- General Design Criteria:
  - Off-site radiation dose
  - Subcriticality
  - Confinement
- Quality Assurance
- Siting
- Physical Protection
- Reporting
- Training and Certification of Personnel

Technical Review Disciplines

- Structural
- Materials
- Thermal
- Confinement
- Criticality
- Quality Assurance
- Shielding and Radiation Protection

Storage System Design Review

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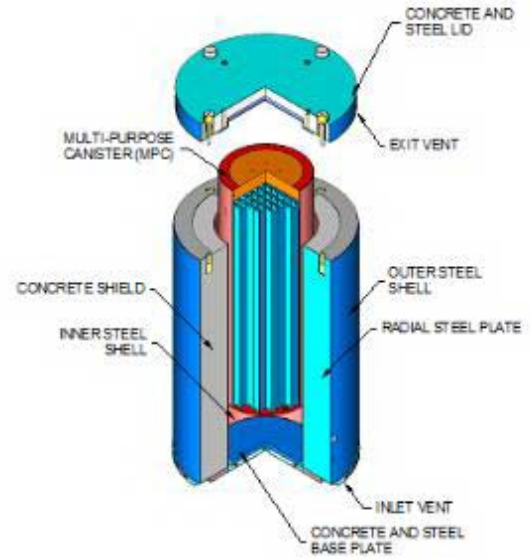
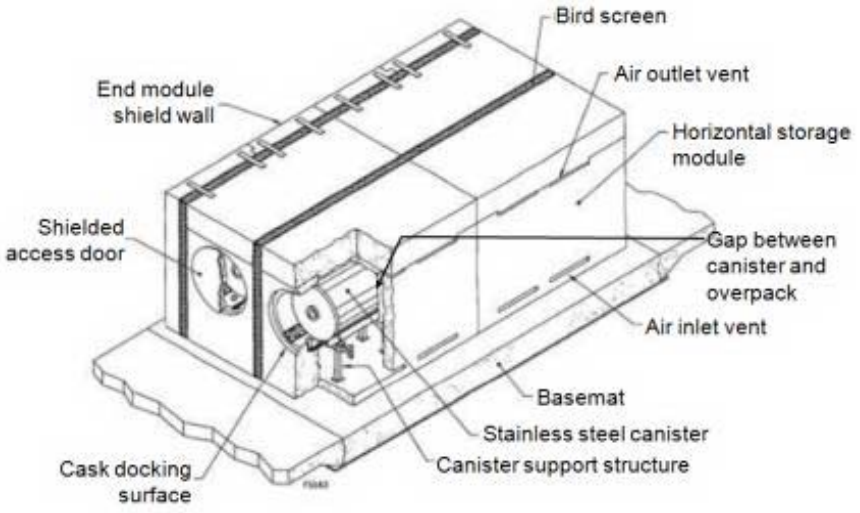
- Normal and Off-Normal Conditions
- Accident Conditions and Natural Phenomena
  - Tornado winds/tornado missiles
  - Floods and tsunamis
  - Earthquakes
  - Fires and explosions
- Technical Reviews:
  - Structural: Confinement maintained under all conditions
  - Criticality: Fuel subcritical under all conditions
  - Shielding: Meets off-site radiation dose rate requirements
  - Thermal: Cladding protected under normal conditions
  - Materials:
    - Materials properties used in evaluations
    - Aging effects managed during renewed storage period

Dry Storage Systems





Storage Renewals

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- Staff renewal review experience:
  - Surry (2/2005)
  - Fort St. Vrain (7/2011)
  - Prairie Island (Hearings)
  - Energy Solutions VSC-24 (CoC) – Ongoing
  - TN NUHOMS® 72-1004 (CoC) – Ongoing
    - Oconee (5/2009)
    - Calvert Cliffs (10/2014)
- Updated Storage Renewal Framework
  - Operations-focused Aging Management
  - Learning, Proactive, & Responsive Aging Management
  - Aging Management Programs that consider and respond to operating experience and results of confirmatory research
- Expected Renewal Applications from 2015 to 2025:
  - 7 Site Specific Independent Spent Fuel Storage Installations (ISFSIs)
  - 8 Certificate of Compliance (CoC) renewals

Aging Management Review for Spent Fuel Storage Renewals

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- Applicants are required to identify aging mechanisms and effects that could affect the ability of the systems, structures, and components (SSCs) from performing their intended functions
- Identification of relevant aging mechanisms:
  - Review of site maintenance records
  - Lead system inspection results (NUREG-1927 Revision 1 Appendix C)
  - Maintenance and inspection records from ISFSI sites with similar SSC materials and operating environments
  - Review of industry records and operational experience
  - Applicable consensus codes and standards
  - NRC reports and generic communications

Aging Management Activities

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Time Limited Aging Analysis (TLAA)

- Typically a calculation to demonstrate an important to safety structure, system, or component will continue to perform their intended function(s) for the period of extended operation
- Examples
  - Fatigue
  - Neutron Absorber Depletion
  - Radiation effects on materials

Aging Management Program (AMP)

- Actions for management of issues associated with aging that could adversely affect an important to safety structure, system, or component
- Examples
  - Localized Corrosion and Stress Corrosion Cracking
  - Concrete Aging
  - High Burnup Spent Fuel Performance

Guidance on Aging Management Programs (AMPs)

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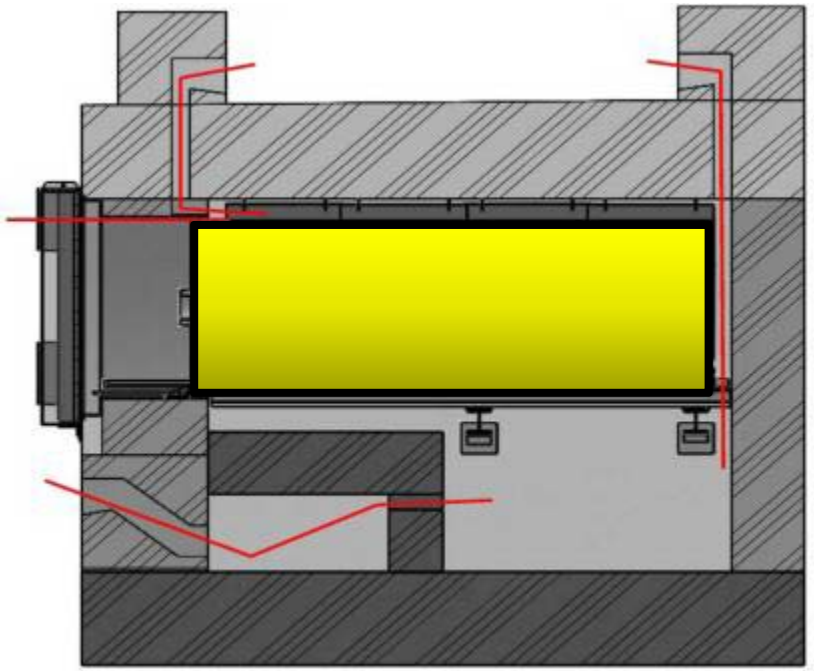
- Specific activities to monitor and control the degradation of SSCs so that aging effects will not result in a loss of intended functions
- Includes all activities that are credited for managing aging mechanisms or effects for specific SSCs
- An effective AMP mitigates or detects the aging effects and includes timely corrective actions
- Required per 10 CFR 72.42(a), 72.240(c)

AMP Elements

1. Scope of the Program
2. Preventive Actions
3. Parameters Monitored/Inspected
4. Detection of Aging Effects
5. Monitoring and Trending
6. Acceptance Criteria
7. Corrective Actions
8. Confirmation Process
9. Administrative Controls
10. Operating Experience

Calvert Cliffs ISFSI Inspection

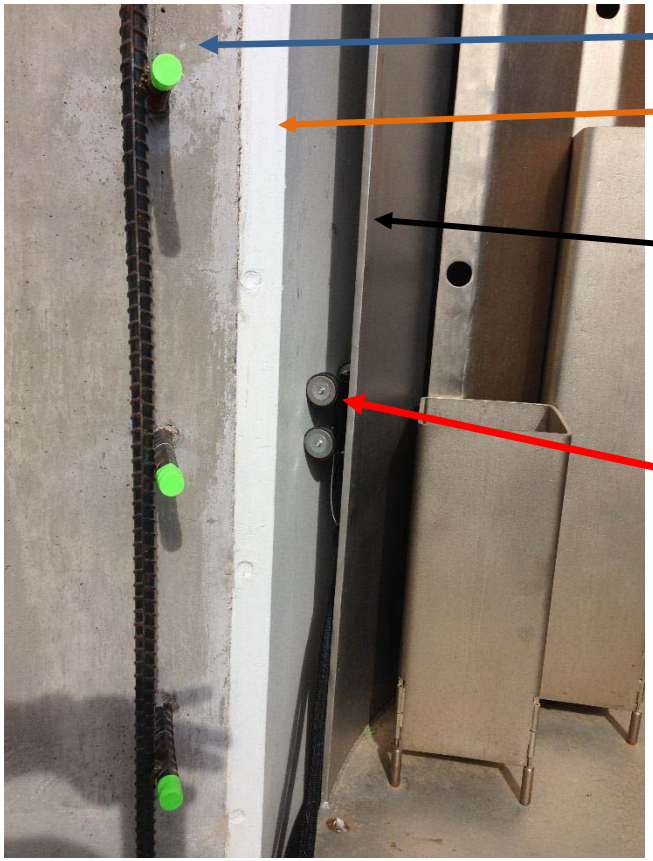


Calvert Cliffs Stainless Steel Dry Storage Canister Inspection.
EPRI, Palo Alto, CA: 2014. 1025209.

Calvert Cliffs ISFSI Inspection

Calvert Cliffs Stainless Steel Dry Storage Canister Inspection.
EPRI, Palo Alto, CA: 2014. 1025209.

Inspection Delivery System



Reinforced concrete

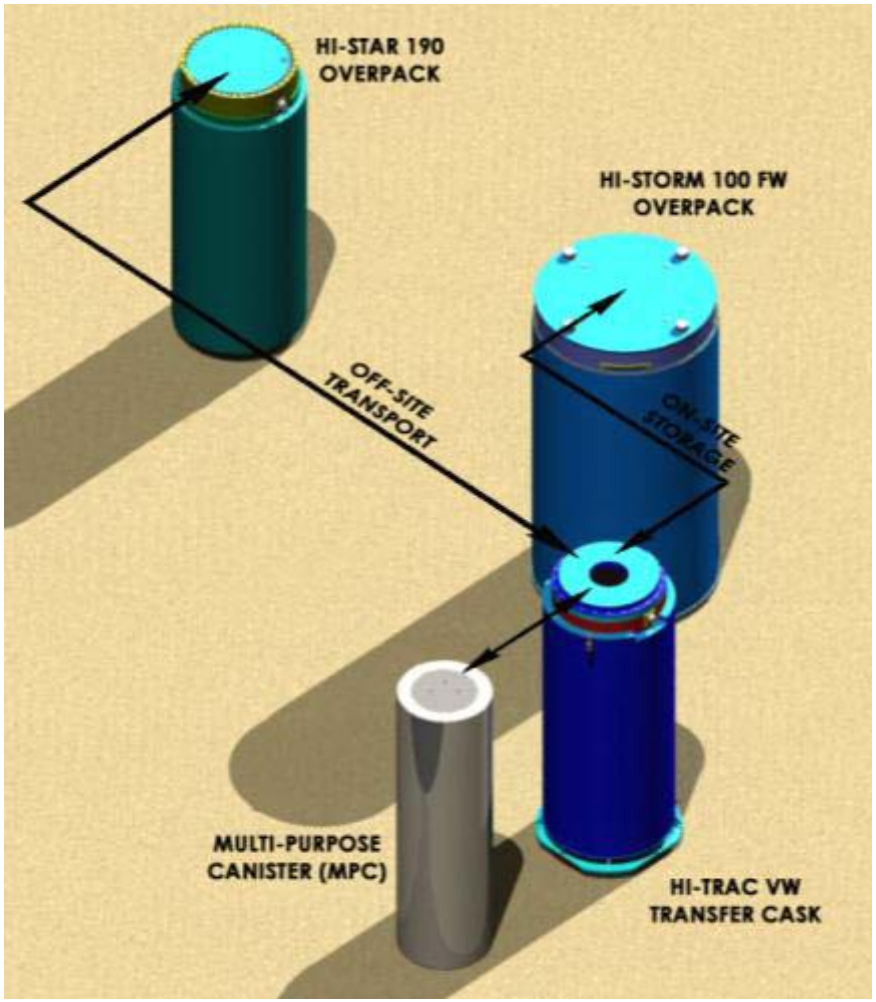
Carbon Steel Liner

Stainless steel Transportation and Storage Canister (TSC)

Remote Inspection Robot w/Magnetic Wheels

Inspection methods:
Eddy Current
Ultrasonic
Visual

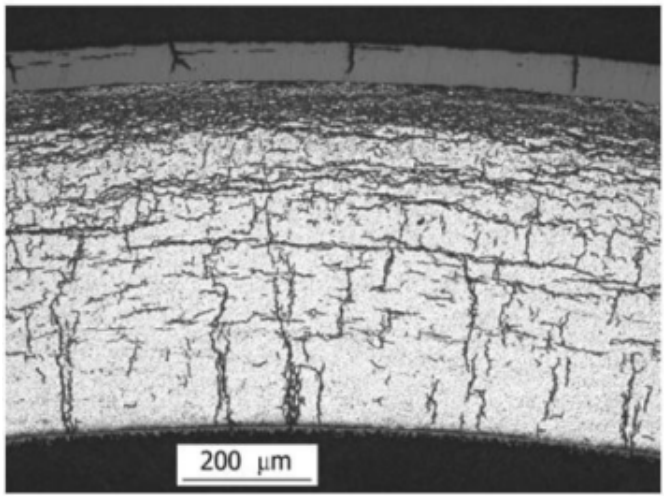
Dual Purpose Systems



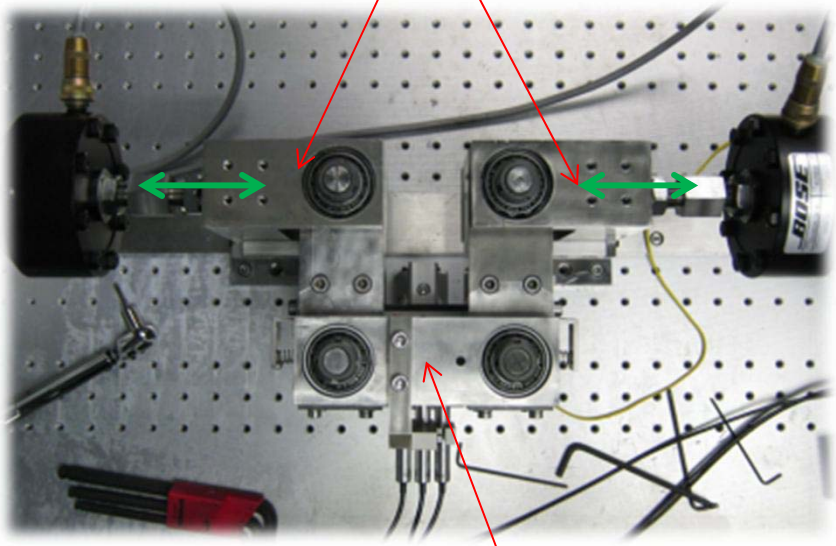
- Multiple designs licensed
  - Direct load casks
  - Canister based systems
- Allows storage then transportation without repackaging fuel assemblies

NRC Sponsored Testing – High Burnup Fuel

- Burnup > 45 GWd/MTU
- Potential Effects:
  - Cladding oxidation
  - Hydride reorientation
  - Hydride embrittlement
  - Creep



Push-pull force applied to U-Frame results in bending moment on the test segment



Location of test segment

NUREG/CR-7198
ML15139A389

NRC Sponsored Testing – Observations

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- Given the Oak Ridge National Laboratory (ORNL) fatigue test results and the expected vibratory loading during transport, fatigue damage laws would predict no cladding failures
- Based on the ORNL fatigue test results High Burnup Pressurized Water Reactor (PWR) Zircaloy-4 spent nuclear fuel can be safely transported with no loss of cladding structural integrity
- Continued vibration testing on other loads and cladding types proposed by the U.S. Department of Energy (DOE)

Ongoing Efforts

- Additional guidance development
  - Managing Aging Processes for Storage, similar to the Generic Aging Lessons Learned (GALL) report
  - Additional non-destructive examination (NDE) guidance
  - Guidance for NRC inspections of licensees' AMA
- High burnup fuel demonstration program
- ASME Section XI Inservice Inspection Code Case
- Continuing stakeholder engagement
  - NEI 14-03 Guidance on Operations-Based Aging Management
  - License Renewal Application Format and Content Guidance
  - Additional inspections / Operational experience / Data collection
    - Inspection coverage and capabilities
    - Lead system selection criteria
  - EPRI activities, research, and reports

Acronyms

- AMA: Aging management activity
- AMP: Aging management program
- ASME: American Society of Mechanical Engineers
- CFR: Code of Federal Regulations
- CoC: Certificate of Compliance
- DOE: Department of Energy
- EPRI: Electrical Power Research Institute
- GWd/MTU: Gigawatt days per metric ton of uranium (fuel burnup)
- GALL: Generic Aging Lessons Learned NUREG-1801 Revision 2 (ML103490041)
- ISFSI: Independent spent fuel storage installation
- MPC: Multipurpose Canister (Holtec International)
- NDE: Nondestructive examination
- NEI: Nuclear Energy Institute
- NRC: Nuclear Regulatory Commission
- ORNL: Oak Ridge National Laboratory
- PWR: Pressurized water reactor
- SSC: Structure, system or component
- TLAA: Time-limited aging analysis
- TSC: Transportation and storage canister (Nuclear Assurance Corporation International)