Licensing Considerations for Dry Storage and Transportation of High Burnup Spent Fuel

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Dry Storage System Design Review

- Normal and Off-Normal Conditions
- Accident Conditions and Natural Phenomena
  - Tornado winds/tornado missiles
  - Earthquakes
  - Floods and tsunamis
  - 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
  - Retrievability: By normal means
- Materials:
  - Properties appropriately assumed in evaluations
  - Aging effects managed during renewed storage period
Transportation Package Design Review

• Same technical discipline reviews as for storage:
  – Ensure that package meets external dose rate limits
  – Ensure fuel remains subcritical
  – Ensure containment is maintained

• Normal & accident conditions differ from storage:
  – Normal transport:
    • Vibration
    • Heat and cold
    • Small drops and impacts
  – Postulated Accidents:
    • 30ft drop on unyielding surface
    • Fire
    • Puncture
    • Water immersion
Potential Material Degradation Mechanisms

• Known potential degradation mechanisms
  – Stress Corrosion Cracking
  – Concrete degradation
  – High burnup (HBU) fuel

• Currently unknown potential degradation mechanisms

• Learning aging management program
Storage Aging Management Considerations

• HBU fuel cladding behavior
  – Hydride reorientation
  – Drying
  – Temperature predictions
    – Vibration response
    – Cladding stress
    – Source Term

• Canister degradation (confinement/structural):
  – Chloride Induced Stress Corrosion Cracking
  – Localized & general corrosion
    – Loss of ductility

• Concrete degradation (shielding/structural):
  – Cracking
  – Loss of strength/bond
    – Spalling and scaling
    – Distortion
Dry Storage HBU Fuel Guidance and Research

- HBU Fuel Monitoring Aging Management Program from SRP for Storage Renewals (NUREG-1927R1)
- ISG-24: Use of a Demo Program as Confirmation of Integrity for Continued Storage of HBU Beyond 20Y
- Monitoring DOE Cask Demonstration Surveillance Program
- NRC HBU Regulatory Issue Summary 2015
- Ongoing confirmatory research activities:
  - Temperature modeling
  - Cladding stress in spent fuel during extended storage
  - Vibration testing program – ORNL
Waste Confidence – Continued Storage Rule

• Addresses environmental impact of continuing to store spent nuclear fuel after the end of licensed life for reactor operations until final disposition in a geological repository

• Analyzed three time frames: short term up to 60 years*, long term up to 160 years*, and indefinite storage

• Generic environmental impact statement includes assumption of repackaging every 100 years

*after end of reactor life
Conclusion

- HBU is safe for storage and transportation
- 10 CFR Part 71 & 72 assures safe storage and transportation of spent nuclear fuel to include HBU through a multi-disciplinary technical review (confinement is key)
- NRC confirmatory research indicates reasonable expectation that cladding won’t significantly degrade in inert environments during storage of HBF for 20 and likely up to 60 years of storage
- DOE HBU Demo Surveillance Program to confirm cladding performance of HBU beyond 20 years
- NRC RIS to identify paths to ensure integrity of HBU cladding during normal conditions of transport when test data is unavailable
- NRC continues to conduct research activities to confirm integrity of HBU cladding during normal conditions of transport
Backup Slides:
High Burnup Spent Fuel
Temperature Modeling

• What are realistic maximum temperatures?
  1. Cladding creep
  2. Hydride reorientation
  3. Cladding stress

• What are realistic lower temperatures?
  1. Cladding DBTT

• How does temperature evolve with time?
  1. Low temperature Creep
  2. Delayed Hydride Cracking
Cladding Stress in Spent Fuel During Extended Dry Storage

• GOAL: Is sufficient cladding stress present to drive the potential for low temperature creep (LTC) and delayed hydride cracking (DHC) failures

• TASK: NRC has performed an analytic study to determine if sufficient of cladding stress exists in spent nuclear fuel (SNF) for a 300 year period of dry storage to drive either LTC or DHC

• This work is part of the ongoing research effort for Extended Storage and Transportation (EST)
Vibration Testing Objective

• Investigate a number of important attributes of the high burnup, fuel/cladding system including:
  – Determining if the presence of fuel increases the flexural rigidity (bending stiffness) of the fuel rod by comparing the moment/curvature relationship from the test to the theoretical results for cladding only. (storage and transport accident)
  – Determining if the presence of fuel increases the failure strain of the cladding by comparing the failure strain from the bending tests to the failure strain from tension tests. (storage and transport accident)
  – Determining the number of cycles to failure for high burnup fuel rods at a range of elastic strain levels. (normal transportation)
Future Vibration Work

- Finalize NUREG/CR report, documenting the results of the Phase 1 testing program (early 2015)
- Finish NRC vibration testing at ORNL on HBF Zry-4 with fuel segments after hydride reorientation - Does it replicate fatigue results with circumferential hydrides?
- Determine Effect of Integrated load
- Integrate DOE replication on other HBF cladding types
- Interact with Sandia, DOE, Railroad Association to determine if vibration is an issue for normal transportation
Spent fuel storage (wet and dry) is safe and secure

NRC continues to evaluate enhancements to safe storage of spent fuel

NRC maintains strong oversight of spent fuel storage

We look forward to receiving the Academy’s insights on spent fuel safety and security

For any questions, please contact:

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