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High Burnup Used Fuel, Full-Scale, Long-Term Demonstration: Logistics

How do We Get the "Must Haves"?

John Kessler

Manager, Used Fuel and HLW Management Program

Keith Waldrop

Sr. Project Manager, Used Fuel and HLW Management Program

INL Workshop: High BU, Full-Scale Demo

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Contents

- Review of “Must Haves”
- What is “prototypic”?
- How do we assure the demo really gets us the “must haves”?
  - Ten years long enough? Need for another 10+ years?
- Example logistics

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Summary of "Must Haves"

- Thermal profiles
- Fuel transfer options
- Monitoring
- UO_2 properties
- Cladding
  - Hydride effects (reorientation, ductile-to-brittle transition)
  - High- and low-temperature creep
  - Helium pressurization
- Other cask internals
  - Fuel assembly hardware corrosion
  - Adequacy of drying

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Other Considerations for Logistics

- Timing
  - When demo needs to start
  - When we need to reopen (for the first time)
- Fuel types
  - Mix of high burnup fuel types
  - PWRs and BWRs? Both? Same cask?
- Sibling rods must be available
- Cladding temperature history (before, during, after demo)
- Available facilities
- Licensing

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What is *Sufficiently* "Prototypic"?

- Peak rod temperature near 400C?
- "Exact" temperature distribution or just close?
- "Exact" cooling rate, or just a lot slower than lab tests?
- Rod basket vs. fuel assembly
- Fuel type
- Burnup and how burnup was achieved
- Include damaged rods?
- Effects on representativeness
  - Fuel handling prior to demo initiation
  - Cask reopening and reclosing effects
    - Thermal
- Other?

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Thermal Issues

- Goals:
  - Confirm models
  - Hit target temperatures
- Short load
- Monitoring
- Assembly selection
- Storage time

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Thermal Profiles Logistics

- Where do thermocouples need to be located?
  - If you can't get them exactly where you want them, how do you determine actual temperatures of interest?
- Data sampling frequency
- Thermocouple longevity
  - How long do they *really* need to last?
  - What data exist on longevity?
  - More long-lasting thermocouples available?
  - Options for replacement mid-test?

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Thermal Profiles Example: CASTOR V/21 Design

- Not possible to locate thermocouples directly on cladding
- Most in guide tubes
- Requires thermal modeling for
  - Thermocouple position selection
  - Interpretation to positions of interest

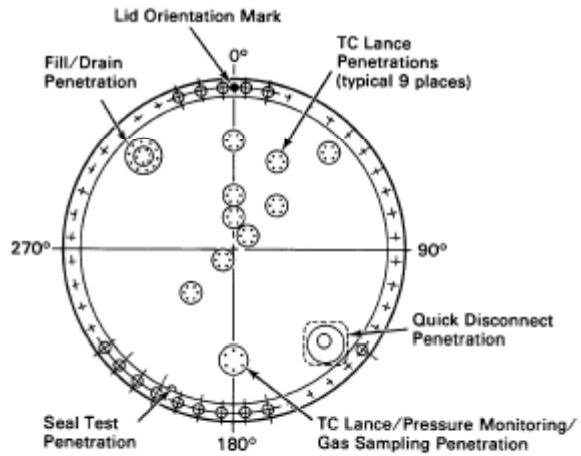

Figure 3-3. CASTOR-V/21 Primary Test Lid

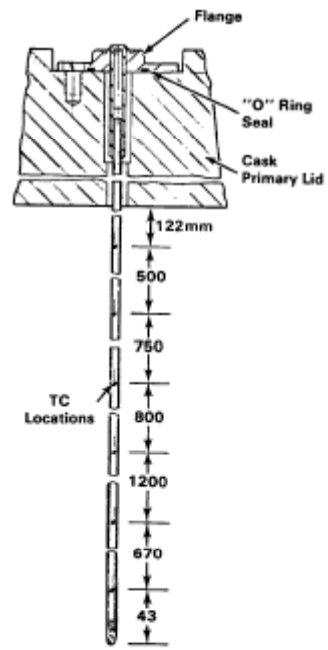

Figure 3-16. Thermocouple Lance

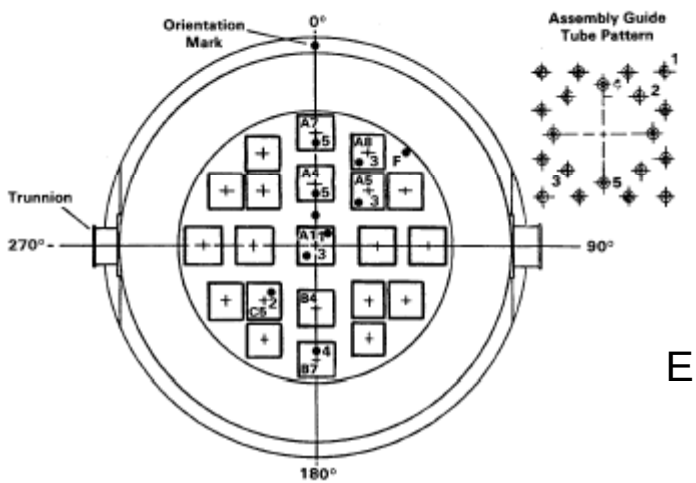

Figure 3-17. Thermocouple Lance Locations

EPRI report NP-4887

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Thermal Design: Peak Cladding Temperatures

- Ensure peak cladding temperatures during drying are near 400C
  - Provides “opportunity” for hydride dissolution/reorientation
  - Tests current US peak cladding temperature limit
  - Requires thermal modeling
    - *Must* be “best estimate”
- Need to mix higher and lower BU assemblies?
- Short load?

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Thermal Design: Cladding Temperatures During Re-opening

- Goal: ensure thermal transients do not affect representativeness
  - What are the concerns?
- Temperature design during re-opening
  - Below conditions for reorientation?
  - Below ductile-to-brittle transition?
  - Benefit to reopening dry versus in a pool?
  - Pick lower decay time assemblies? [more rapid temperature drop than older assemblies]

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Thermal Design: Temperature Restrictions During Pre-demo Transport and Loading?

- Avoid “significant” cycling up to near 400C: ±60C?
- Potential cycles if fuel is transported to another location for the demo:
  - Drying prior to transport (temperature increase, then decrease)
  - Transport (temperature increase or decrease)
    - Peak temperature a function of number of assemblies shipped, BU, decay time, season
  - Unloading into demo cask (temperature cycles if multiple loadings are required)
  - New lid emplacement (temperature increase)
  - Vacuum conditions (temperature increase)

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Fuel Transfer from Multiple Reactors

- Non-technical issues:
  - Contracts
  - Fuel ownership
  - Public acceptance
- Transportation of full, high burnup assemblies
  - Available systems (light-weight/heavy haul trucks)
  - Thermal and water history of transported assemblies – does it make them non-prototypic?
  - Need sibling rods from multiple locations
- Cost/benefit compared to using assemblies from just one reactor
- Would this affect when demo is loaded

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Fuel Transfer to Test Location Options

- One or two assemblies at a time
- Entire cask

- Considerations
  - Cost
  - Time to complete shipment
  - Fuel environmental conditions prior to demo initiation
    - Thermal during drying, transport, emplacement in demo cask
    - Impacts of leaving “early arrival” assemblies in air until cask is fully loaded

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Desire to Perform All Operations Dry

- What magnitude of thermal transient must we avoid and why?
  - Does reopening dry (versus wet) avoid this magnitude?
- Need for dry handling facility:
  - What kind of facility?
    - Equivalent of old TAN facility?
    - Dry Transfer Facility?
  - When?
  - Where?
- If we dry prior to shipment and then pull a vacuum again at the beginning of the demo is that prototypic?
  - Loss of ability to test adequacy of drying

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Avoid Delay of First Demo Initiation

- If 100% dry handling is essential:
  - If demo is full-scale and at a new facility: need an acceptable location, funding, construction, and performance of pre-op checks first. How fast can we expect this to happen?
  - If demo is full-scale and at a utility (or other location) with a pool: we need a dry handling facility prior to unloading
    - Buys us time
    - But then the fuel must be transported to new location dry
- Part-scale could avoid delays:
  - Is a part-scale test prototypic?
  - If not, can it be made to be prototypic (sufficient to *eliminate* need for full-scale demo)?
  - Part-scale casks available?

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Rewetting/Redrying Issues

- Evaluate impacts on representativeness
  - Rewetting:
    - Thermal shock
    - Effect of dropping temperatures to pool temperature
    - SET needed
  - Redrying:
    - Determine maximum drying temperature
    - How do we determine dryness?
  - Do we have to wait for these evaluations before committing to wet?
- Alternative: demo cask transport to another location
  - Needs proper design and licensing

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Monitoring: Gas Pressure and Sampling Logistics

- Ease of use
- Reliability, leak-tightness
- On-line sampling?
  - Which gases? (hydrogen, Xe/Kr, water, oxygen, helium)
- Gas sample collection

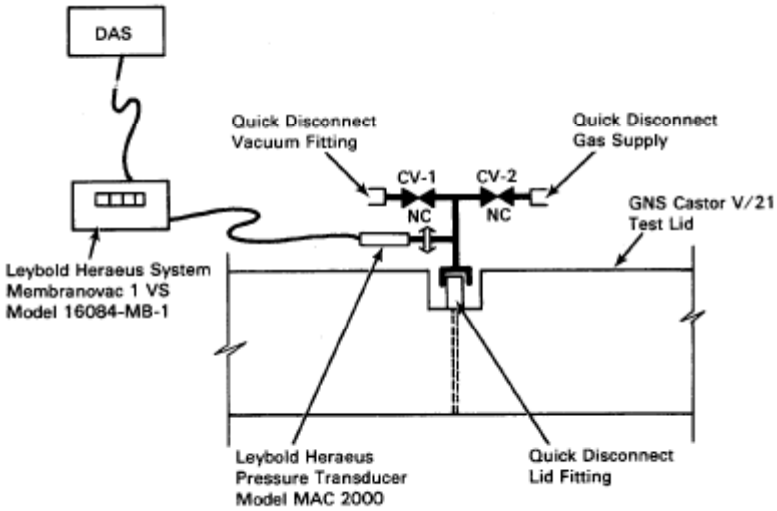

Figure 3-5. Pressure Transducer Valve Tree

CASTOR V/21 Gas Sampling System [EPRI NP-4887]

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Any Other Monitoring?

- Must haves?

- Nice to haves?
  - Remote monitoring system: wait for development?
  - Creep (strain gauges?)

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Cladding Swelling, Pellet-Cladding Interactions

- How do we determine this?
  - Puncture test
  - Modeling of extra rod gas pressure
    - Need model of fraction of fission gas in gap
    - Need high burnup UO_2 properties
      - Tensile strength
      - Expansion under tension
- How do we find PCI locations?

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Full-Scale Demo: Example Logistics

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Full-Scale Demo Example Logistics: Select Cask Type

- Cost (is one already available?)
- Is cask vendor a willing partner? [Read “cost share”]
- Amenable to desired instrumentation?
- Amenable to reopening (multiple times)?
- Licensable for high BU storage (and maybe transportation, too)?
  - Any options that avoid need for licensing?
- Find qualified fabricator
- Construction lead time (cask body and special lid)

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Full-Scale Demo Example Logistics: Select Fuel

- Optimal: multiple, high BU fuel types
- Identify available fuel population
  - Fuel characteristics that are needed for selection:
    - Burnup distribution
    - Reactor operating history
    - Fuel type, dimensions, construction methods and materials
- Necessary to mix with other fuel (or short load) to meet temperature restrictions
  - Thermal modeling required for fuel selection and emplacement positions to meet all temperature criteria

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Example Logistics: Fuel Selection (continued)

- Need success path to agreements with each utility owning the candidate fuel. Agreement issues:
  - Fuel ownership transfer
  - Liability
  - Utility requirements to confirm fuel is intact
  - Who pays for what?
- Any special transportation logistics issues?
  - Full assemblies or pins?
  - Number of shipments
  - Are the required transport casks available?
  - Special licensing issues?

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Example Logistics: Fuel Selection (continued)

- All candidate assemblies must have available sibling assemblies or rods
  - How many are needed for pre- and post-test characterization?
  - Utility must properly manage assemblies/rods until time of characterization
  - Put rods for post-testing in a special can inside the cask?
  - If rods are to be shipped, utility and/or fuel vendor must develop procedure to pull rods that meets both demo and utility used fuel management criteria
  - Agreements between utility, shipper, funding organization(s)

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Fuel Pre-Characterization: Data to be Collected

- Must haves?
  - Profilometry (creep baseline)
  - Rod gas pressure and content (cladding stresses, f.p. gas in gap)
  - Hydrogen content and orientation (initial hydride concentration and radial distribution)
  - Oxide thickness (cladding stresses)
  - Ductility vs. temperature (DBTT)
- Nice-to-haves?
  - Ceramography (hydride platelets characterization)
  - Hydride reorientation conditions (function of cladding stress and temperature)

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Example Logistics: Fuel Pre-Characterization

- Identify candidate testing facilities
  - Cost and timing
  - Operational or transportation restrictions?
  - Relative expertise including QA
  - Licensing, contractual, international issues
  - Other restrictions (e.g., waste management, state/local laws)?
- Assuming all tests not possible at the same facility:
  - Agreements between utility and testing facilities
  - Shipment of sibling rods or rod parts

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Example Logistics: Demo Cask Lid Modification

- Design must meet all criteria:
  - Obtain necessary samples/data
  - Appropriate frequency
  - Monitoring system reliability and longevity
- Licensing issues, especially confinement:
  - Special lid penetrations
  - Is it transportable
  - Handling procedures are reasonable
  - Will require preliminary design and pre-licensing discussions
- Will lid and thermocouples need to be emplaced and removed multiple times?

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Example Logistics: Dry Runs and Pre-Checks

- Load dummy assemblies and install lid with thermocouple lances
- Ensure leaktightness of lid and gas connections
- Ensure all monitoring components are working
  - Thermocouples
  - Pressure gauge
  - Gas sampling

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ISFSI Issues

- Existing ISFSI?
- DOE or Part 72?
- If Part 72, general or site-specific?
- Where will it be stored on pad
- Special wiring for added instrumentation – does it already exist or do we need to add more capabilities for remote monitoring?

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Example Logistics: Cask Loading

- Develop procedures
- Will fuel arrive in multiple shipments?
  - Consider impacts of time it takes to completely load
    - Fuel remains in air until completely loaded
    - Time at temperature in air
    - Temperature cycling as lid is removed and replaced
- Follow all usual drying procedures
  - Should we allow peak cladding temperatures to rise to just under 400C by holding the vacuum?

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Example Logistics: Reopening and Rod Extraction

- Licensing “logistics” for dry opening
- Wet/dry
- Pulling rods
  - Top nozzle removal/replacement
  - Pre-pulled rods?

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Licensing "Logistics"

- Pre-licensing discussions
  - What we want to do
  - How we propose to do it
  - How we will meet regulations
    - Exemptions
- Licensing
  - Storage only?
  - Transportation?
  - Develop exemption rationale
  - SAR

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Cask Re-loading and Re-initiation

- What mechanisms require a second period of storage to uncover?
  - Low temperature creep
  - Other?
- What to reload it with?
  - Opportunity to introduce new fuel or other instrumentation?
- Procedures
  - Revised temperature limits
  - If loaded wet, establish new drying procedure
    - Use gas sampling shortly after redrying to determine dryness?

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