Achieving Moderator Exclusion for Transportation

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The Blue Ribbon Commission

- The Draft Report of the Transportation and Storage Subcommittee of the Blue Ribbon Commission posed two questions:
  - *"Are there technical or regulatory uncertainties related to the ability to store existing and future spent fuel and high-level waste safely and secure for an extended period of time (100 years or more) and then transport it safely and securely to another location?"*
  - *"What are the key issues that will affect the ability to transport spent fuel and high-level waste now and in the future at the scale that will eventually be required?"*
- The Department of Energy's Office of Nuclear Energy, under the Used Nuclear Fuel Disposition technical area, is addressing these questions and more with investigations into various storage, transportation, and disposal issues for commercial used fuel (nominal and high burnup)
- As part of that effort, Idaho National Laboratory addressed moderator exclusion [not allowing moderator (water) to enter the used fuel cavity]

The Problem

- Commercial used fuel may remain in storage longer than initially expected
- For transportation after storage, the transportation package is expected to adequately provide the necessary containment and shielding needs for safe transport but criticality concerns are unique
- After long-term storage, the structural integrity of items [e.g., used fuel (including cladding), poisons, or baskets] inside of the storage canister may degrade, making it difficult to ascertain if the transportation package can satisfy current criticality safety requirements
  - Unexpected changes, material degradation, or greater than expected deformations may arise
  - Difficulty in proving that the condition of items inside of a storage canister have not been adversely affected
  - Justifications may prove to be too costly
- Repackaging used fuel is not desirable

Difficulty With Existing Regulatory Approach

- 10 CFR 71.55(b) requires the assumption of water leaking into or liquid contents leaking out of the containment system for maximum reactivity
- This assumption has historically been applied to both normal and hypothetical accident conditions
- The NRC has recently allowed moderator exclusion for hypothetical accident conditions with appropriate justification
  - HI-STAR 180
  - NRC's SFST-ISG-19 for high burnup fuel
- Moderator in-leakage for normal conditions of transport is still a required assumption for general approval of designs

The Need for Moderator Exclusion

- Commercial used fuel, whose enrichment is limited to 5 wt. % U-235 cannot become critical in the absence of a moderator
- If the used fuel, baskets, or poisons become degraded (or if determining their actual condition cannot be adequately justified) and the transportation package cannot satisfy criticality safety requirements, the most effective solution is to not allow moderator to enter the used fuel cavity
- This solution should apply to both normal <u>and</u> hypothetical accident conditions

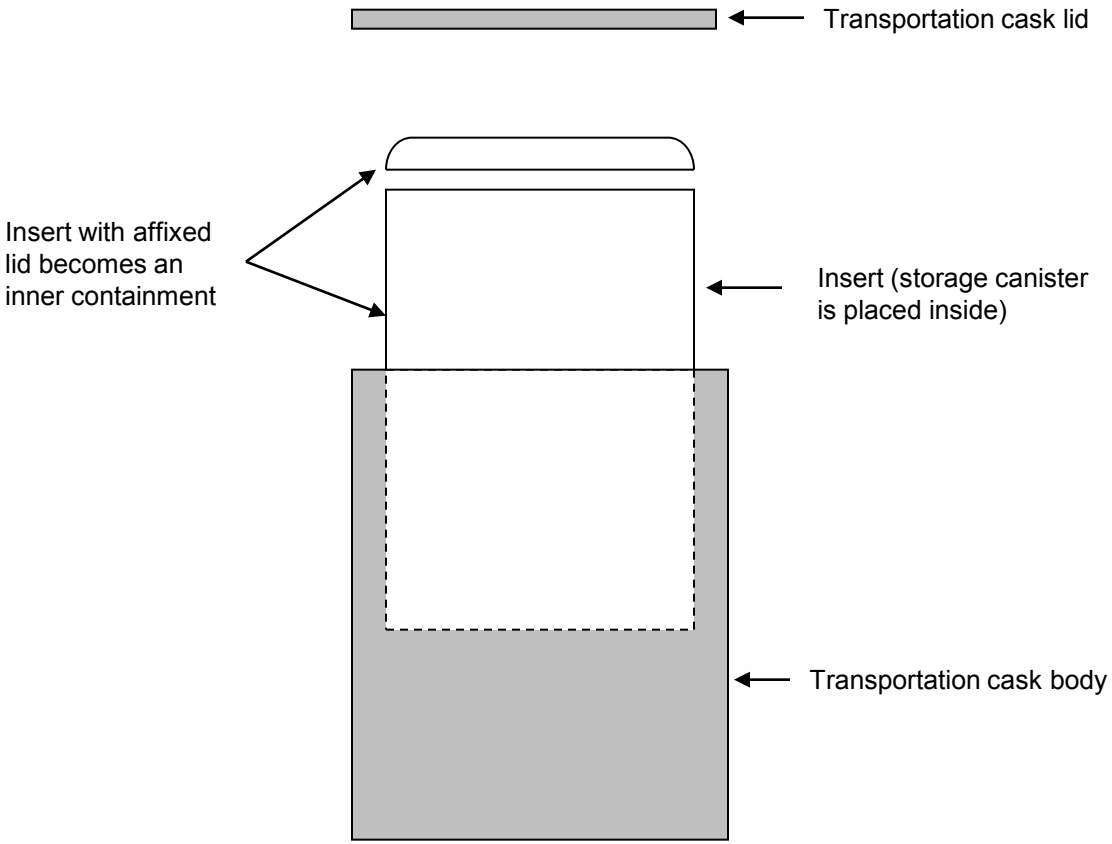
Proposed Concept for Moderator Exclusion

- Basic principle of defense-in-depth is the use of multiple barriers
- Proposed concept is to provide a separate and distinct component inside of a transportation cask capable of performing the watertight function needed to achieve moderator exclusion
  - Acts as a special design inner component ensuring no single packaging error would permit in-leakage of moderator
  - Inner component can be physically leak tested to demonstrate its capacity to be watertight
- This concept is believed to satisfy the conditions of 10 CFR 71.55(c)

Implementation of Proposed Concept

- Prior to any transportation effort, determine if moderator exclusion is necessary or not
- If moderator exclusion is not necessary, the storage canister can be transported inside of the transportation cask as is
- If moderator exclusion is needed, then a component is needed to provide the watertight function
  - Storage canister, or if not capable
  - A separate additional inner containment that can completely enclose the storage canister

Concept Sketch



Similar Approach to IAEA Standard & Past

- Current international transportation safety standards do not require the assumption of moderator leakage past multiple barriers (2009 Edition, IAEA TS-R-1)
  - Not less than two high standard water barriers
  - Each barrier can be demonstrated to remain watertight under:
    - normal conditions followed by
    - accident condition tests (immersion test varies)
  - Test to demonstrate the closure of each package before each shipment
- Historical uses of an inner containment:
  - Transportation package for TMI-2 core incorporated a separate inner containment
  - 10 CFR 71.63(b) for plutonium shipments used to require separate inner containers

Standardization Enhanced

- Placing a storage canister into a transportation cask not custom built for that specific canister could be problematic
  - Rattle around due to gaps
  - Increased impact loadings
- A reusable transportation cask insert that adapts to the geometry of the storage canister provides better support and protection to the canister and the insert can be designed to effectively absorb impact energy
- Few transportation packagings currently exist worldwide that can ship a commercial storage canister
- DOE can effectively move forward by building a fleet of standardized transportation packagings that can accept a range of existing storage canisters using an insert concept with multiple designs
- The insert can become an inner containment (the watertight component) by affixing a sealable lid when needed for moderator exclusion

Benefits of Proposed Concept

- The insert/inner containment:
  - can adapt a single transportation packaging design into a system of custom fit packagings, able to transport many geometries
  - is less expensive to construct than a complete transportation cask
  - can be reusable
  - provides an inspectable component that can be leak tested immediately prior to shipment
  - fabricated of new material, reduces or eliminates the potential need to inspect, examine, or test aged storage canisters, reducing costs and personnel radiation exposures
  - increases operational safety and cost efficiency as a result of standardization and procedural consistency
  - allows flexibility in the scheduling use of the transportation packaging via staging, reducing turnaround time
  - serves as an unshielded enclosure to safely handle significantly degraded storage canisters

Proposed Concept Summary

- Current storage practices (using an inert atmosphere, leak testing to demonstrate the integrity of the canister, using durable materials, etc.) must continue to protect against degradation effects
- Current R&D should continue to investigate long-term storage consequences but an alternative option is also needed
- The proposed concept permits regulations to focus on the accessible item in storage, the storage canister (rather than the used fuel, baskets, or poisons inside of the canister) or a new, non-degraded inner containment
- The proposed concept brings the handling of fuel into a new light - canister retrievability rather than fuel retrievability - a more desirable goal versus the alternative of repackaging

Conclusions

- It may be desirable to have alternative approaches (in addition to demonstrations of fuel integrity) to meet 10 CFR 71.55(b) criticality requirements for transportation
- Request that the NRC consider this proposed concept approach when deliberating the potential for regulatory changes as part of their on-going Regulatory Program Review for Extended Storage and Transportation
  - Allow general use of 10 CFR 71.55(c) option with appropriate justification
  - Maintain current storage practices (inert atmosphere, leak testing, durable materials, etc.)
- Additional justification for regulatory change can be provided based on probabilistic risk assessments that reflect the use of a watertight inner component (storage canister or inner containment) for both normal and hypothetical accident conditions