Criticality Safety Strategy

Packaging DOE SNFs for an Uncertain Future

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Criticality Safety Strategy

To identify a canister fissile loading limit that assures criticality safety requirements for storage, transport, and disposal are satisfied

Any Questions?

- Why are we still doing criticality analyses?
- Why are we still planning to use the standardized canister?
- How can we ensure safety for loaded canisters without fuel-specific criticality analyses?
- How will the canister fissile loading limits be derived?
- Won’t this approach limit us to unacceptably low fissile loadings?
- Can it really be that easy?
- Will this approach be successful?
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Why are we still doing criticality analyses?

- The next time we repackage DOE SNF should be the last time we repackage DOE SNF
  - At some point, fuels will likely be repackaged
  - Package should meet requirements of all remaining phases of the life cycle (storage, transport,……, and disposal)
  - Package should address disposal-related criteria

- Repository criticality analyses have provided valuable insights
  - Post-closure criticality analyses are relatively independent of repository medium
  - Analyses are relatively independent of fuel properties
  - Fuels can be packaged with a high degree of confidence that they will be acceptable for a range of future disposal scenarios

- Henry Loo has retired …….. and Larry Taylor will soon expire

Why are we still planning to use the standardized canister?

- Safe and cost effective
  - Standardizes operations, tooling, and analyses
- Incremental cost for canister is small
- Added versatility/flexibility is significant
  - Addresses broad range of potential storage, transportation and disposal options
- Sound strategy for packaging DOE SNFs
  - Exception may be fuels that are candidates for reprocessing

How can we ensure safety for loaded canisters without fuel-specific criticality analyses?

- Avoid crediting fuel-specific properties
  - No credit for fuel geometry
  - No credit for moderator displacement of fuel matrix material (e.g. model fuel as uranium/water solution)
- Credit performance of canister and canister internals
  - Canister constrains geometry
  - Canister prevents moderator intrusion during storage and handling
  - Basket displaces moderator, constrains movement, and may contain advanced neutron absorber material
  - If needed, free-flowing beads can be installed to displace additional moderator, further constrain and protect fuel, and insert additional neutron poison
- Credit gravity and entropy

How will canister loading limits be derived?

- Identify the most reactive configuration for a given canister/canister internal configuration

Criticality Dashboard

Canister Parameters

Diameter

- (●) **18"**
- ( ) 24"
- ( ) …

Length

- ( ) 10'
- (●) **15'**
- ( ) …

Internal Environment

- ( ) Dry (as-loaded condition)
- (●) **Flooded (breached)**
- ( ) …

Reflected by

- ( ) Air
- ( ) Water
- (●) **HLW**
- ( ) Other
- ( ) …

Payload

20 # FHUs/Canister

Basket Parameters

Basket Type

- (●) **Type 1a**
- ( ) Type 2
- ( ) Type 3
- ( ) Type 4
- ( ) Type 5 (square)
- ( ) Type 6 (rectangle)
- ( ) Type 7
- ( ) Type 8
- ( ) Type 9
- ( ) …

Quantity (# baskets)

- ( ) 1-Stack
- ( ) 2-Stack
- (●) **3-Stack**
- ( ) 4-Stack
- ( ) 5-Stack
- ( ) 6-Stack
- ( ) …

Condition

- (●) **Intact (as-loaded)**
- ( ) Collapsed
- ( ) Degraded
- ( ) …

Poisoning

- ( ) No poison
- (●) **Plates with Gd**
- ( ) Beads with Gd
- ( ) Plates & Beads with Gd
- ( ) …

Fuel Parameters

Type

- (●) **ATR**
- ( ) ORR
- ( ) MURR
- ( ) MIT
- ( ) …

Condition

- ( ) Intact
- ( ) Degraded - rubble
- (●) **Degraded - homogenized solution**
- ( ) …

Axial Distribution of Fissile Material

- ( ) As-loaded
- ( ) Distributed over FHU length
- (●) **Distributed over canister cavity length**
- ( ) Other, specify:
- ( ) …

Radial Distribution of Fissile Material

- ( ) As-loaded
- ( ) Distributed over FHU cross-section
- (●) **Distributed over canister cross-section**
- ( ) Other, specify:
- ( ) …

Payload

93.15% BOL Enrichment (%)
1.075 Fissile Mass/FHU (kg)

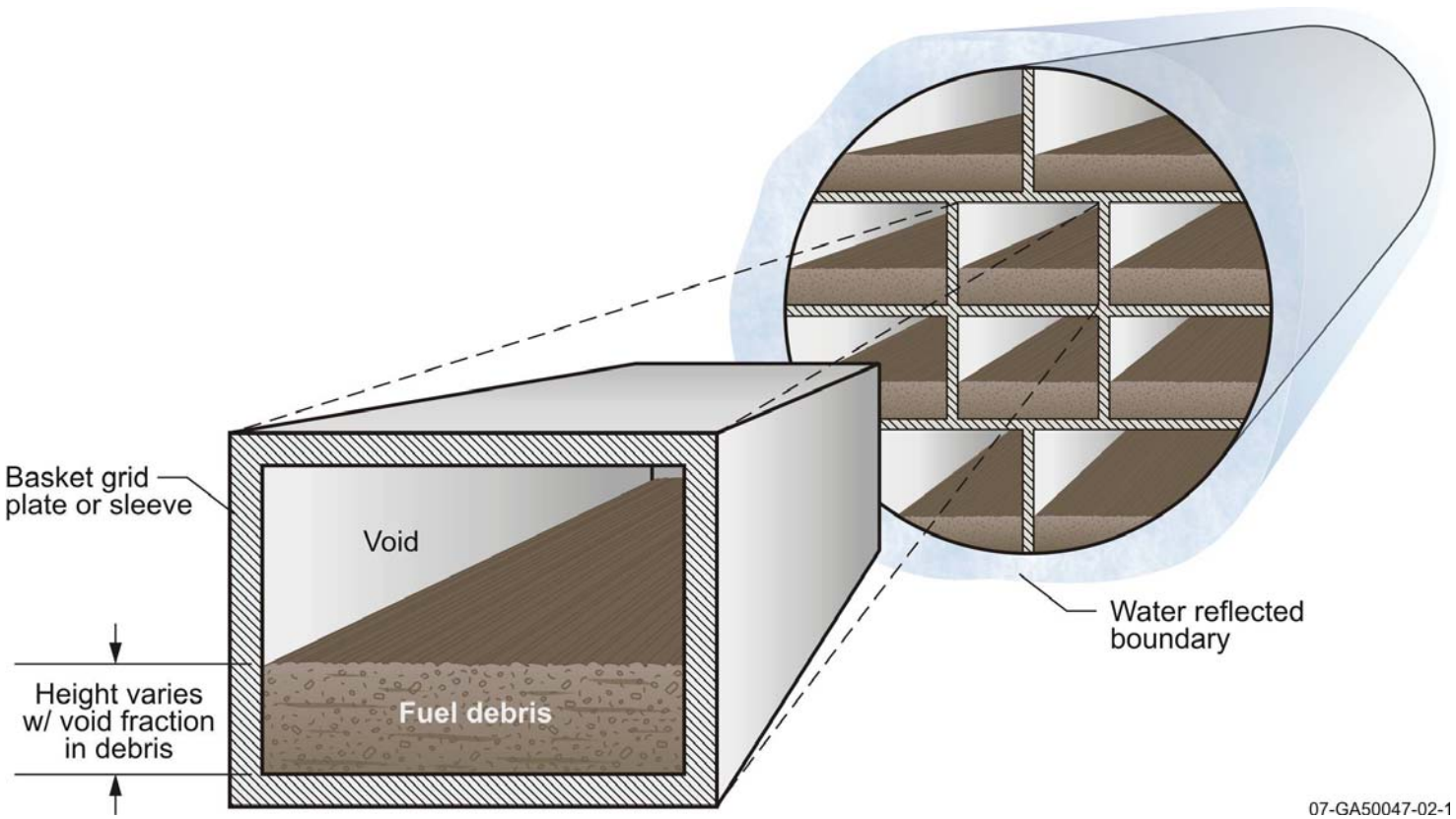
k_{eff}

0.9510 $k_{eff} + 2B$

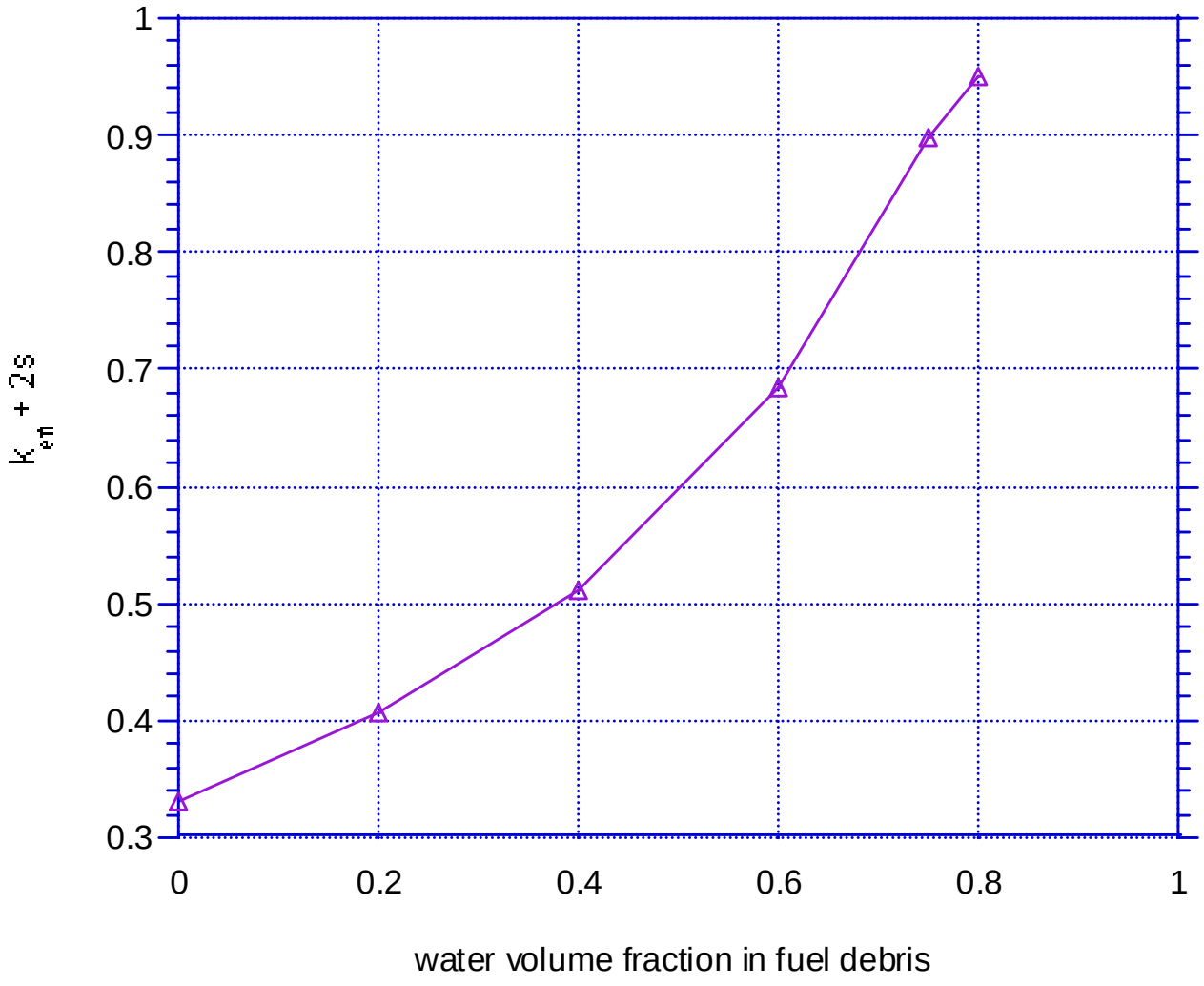
Legend
User Input

FHU = fuel handling unit

Determining Most Reactive Radial Distribution



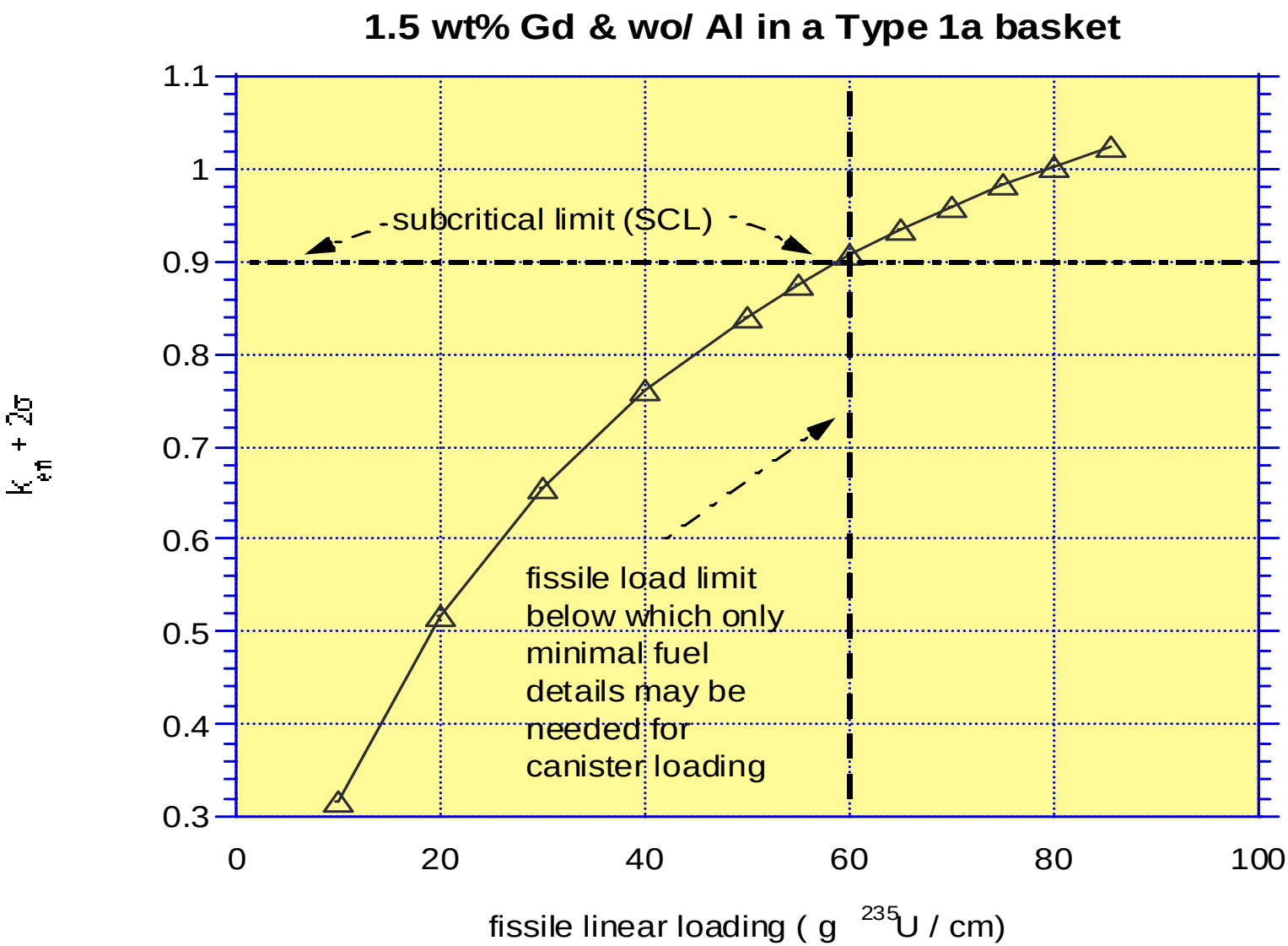
Determining Most Reactive Radial Distribution



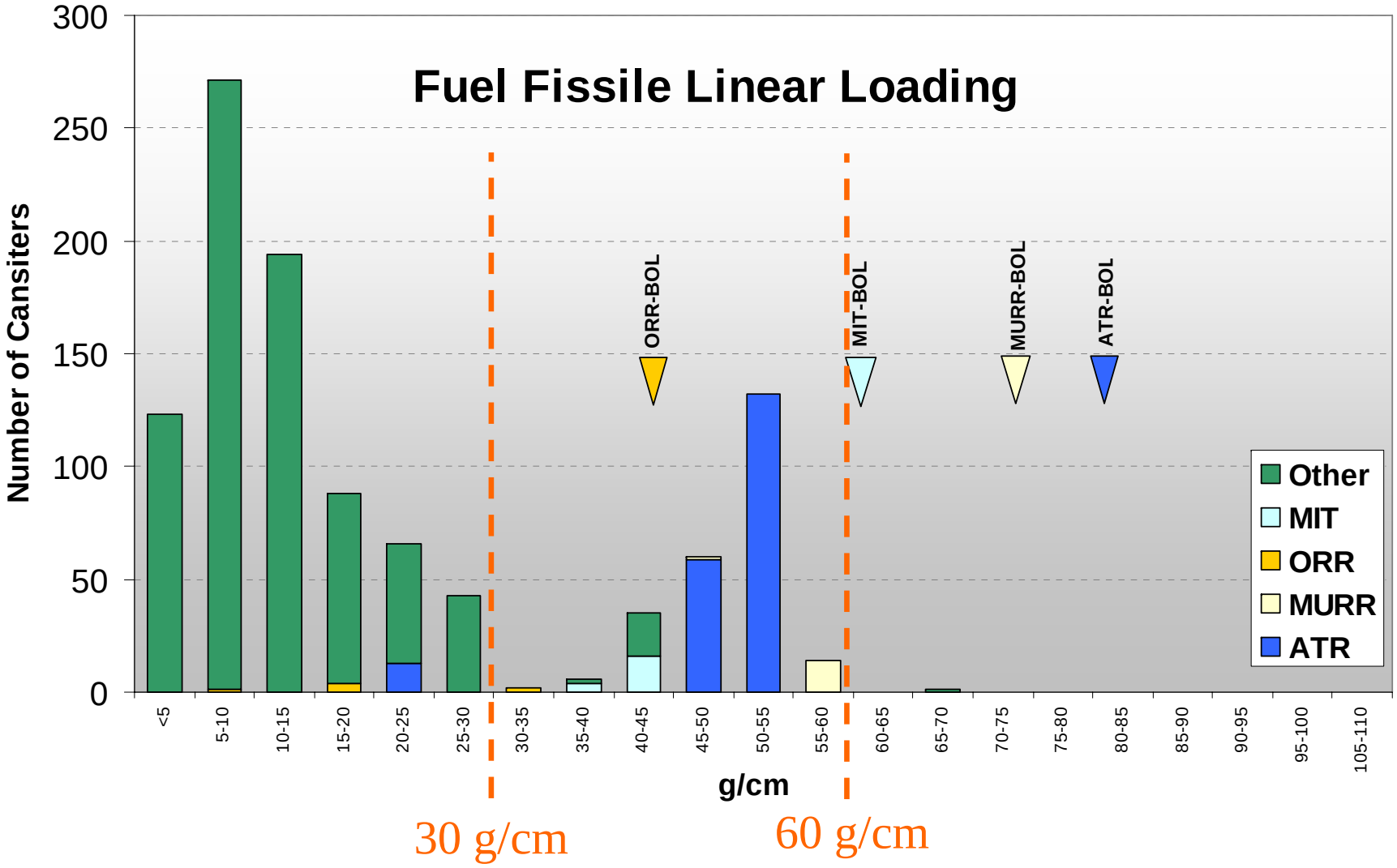
How will canister loading limits be derived?

- Identify the most reactive configuration for a given canister/canister internal configuration
- Perform a parametric analysis of K_{eff} vs. fissile loading for the most reactive configuration
- Establish a fissile loading limit below which the subcritical limit cannot be exceeded

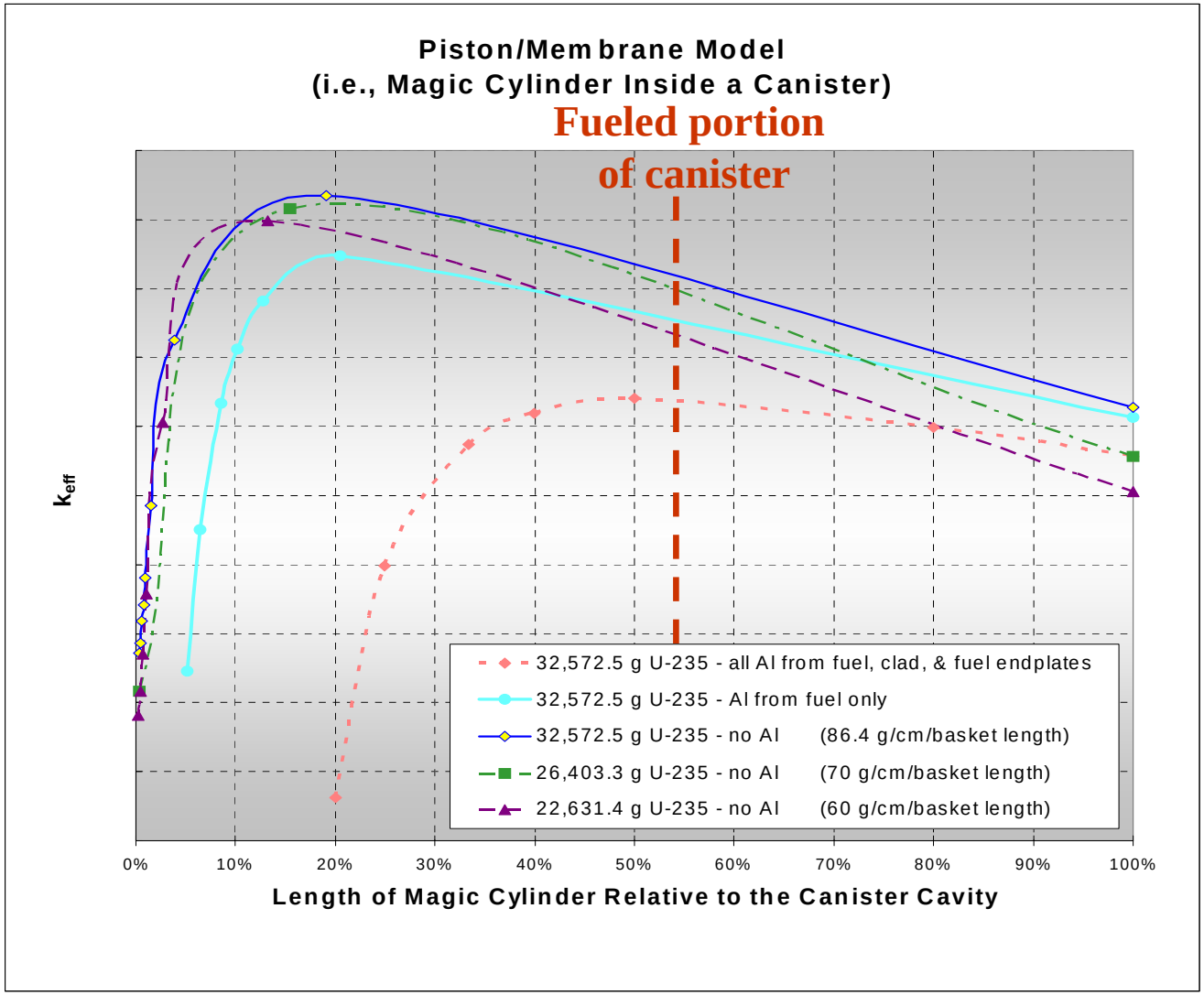
Proposed Use of a Fissile Linear Loading Limit



Will this limit us to unacceptably low fuel loadings (i.e. require additional canisters)?



Can it really be that easy?



Will this approach be successful?

- Yes for storage and handling (no moderator intrusion)
- Yes for repository (no axial concentration, risk based)
- Yes but ….. for transportation. Due to potential for axial concentration of fissile materials – we must credit something else
  - Geometry …. requires fuel-specific mechanical/chemical properties
  - Poison ….. requires demonstrating sufficient poison will remain in proper locations relative to fissile material
  - Moderator exclusion … requires NRC acceptance and perhaps rulemaking
  - Moderator displacement…. requires use of inert filler material (e.g. steel shot, poisoned beads)

Strategy: Remain Flexible …… while moving forward

- What we should plan for….
  - DOE SNF will be stored for many more years
  - DOE SNF will require transport following storage
  - The endpoint for many DOE SNFs will be disposal

- The standardized DOE SNF canister is compatible with all of the above
  - Canister internals and loading criteria must be developed to ensure canister loadings will satisfy criticality safety requirements for a range of credible paths and endpoints