Neutronic Isolation Media for Degraded Spent Fuel Storage in Casks

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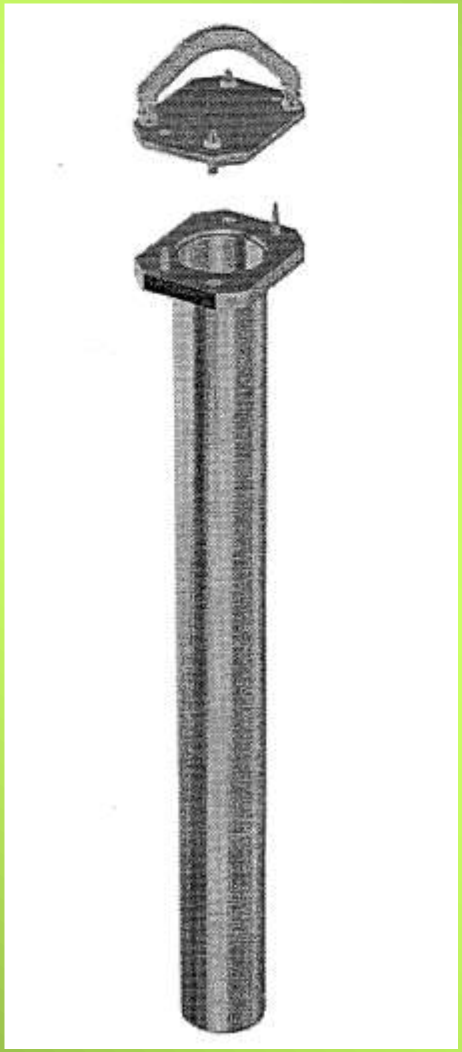
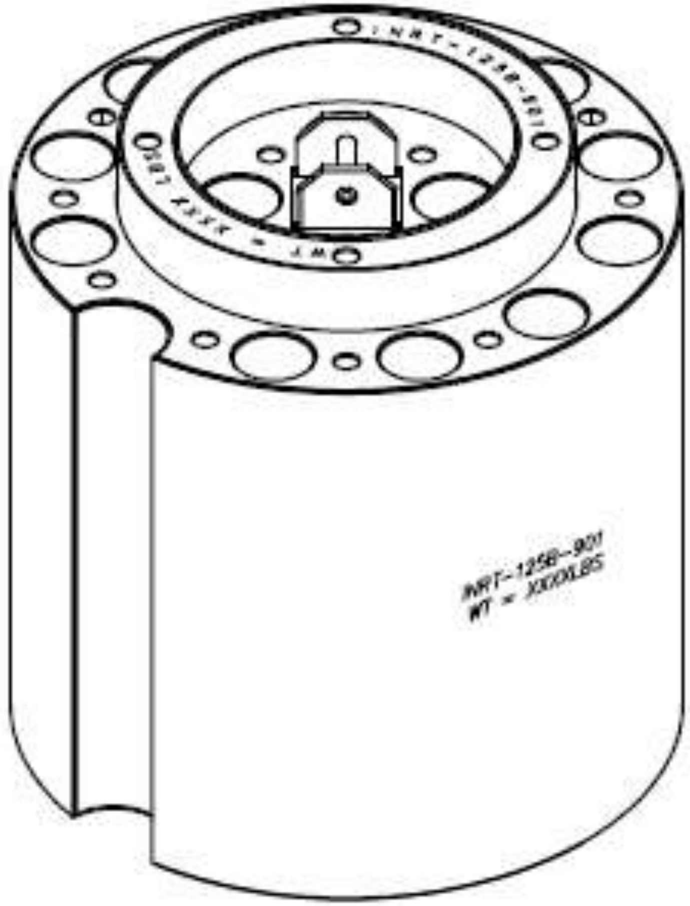
Introduction of Problem

- Interim Storage of SNF in Casks
- Degraded fuels in water filled, non-draining storage cans (5” diameter)
  - Requires conservative (homogeneous) modeling, fuel is well moderated
- Cask to be drained of water
  - Causes significant interaction between fuel cans
- Goal to maximize number of fuel cans to be stored in cask
- Up to 1400 grams U-235 per can
- Various cask insert fill (isolation) materials investigated

Fuel Can



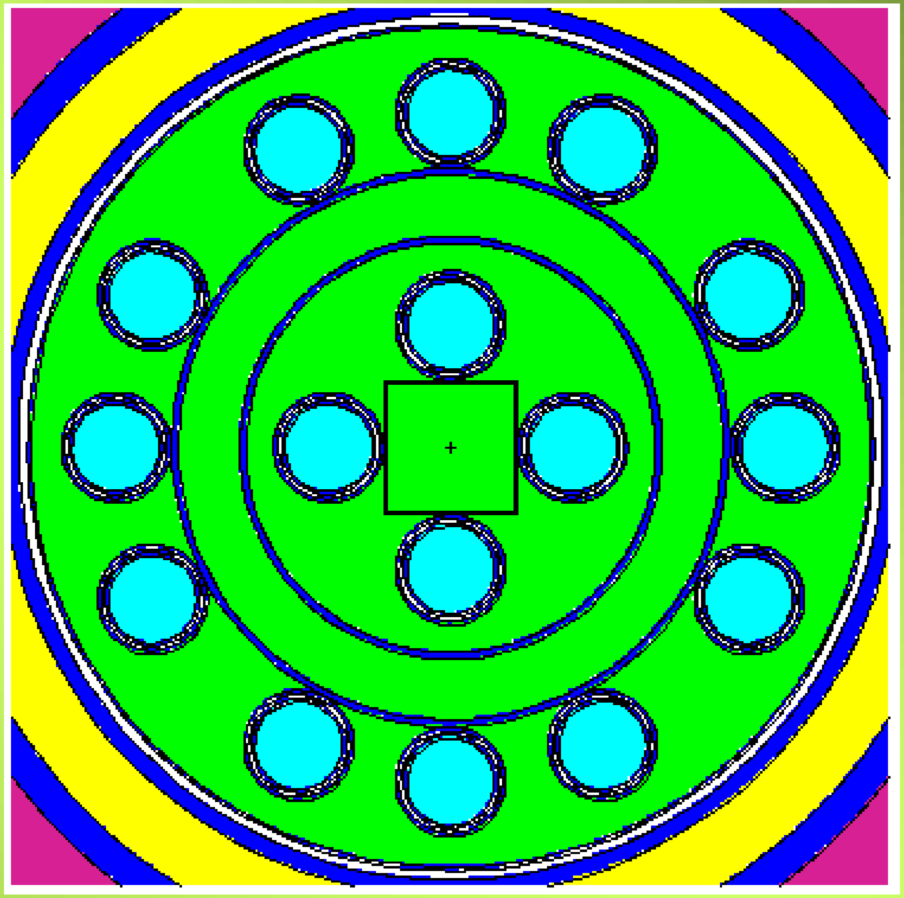
Cask Insert



Cask Modeling

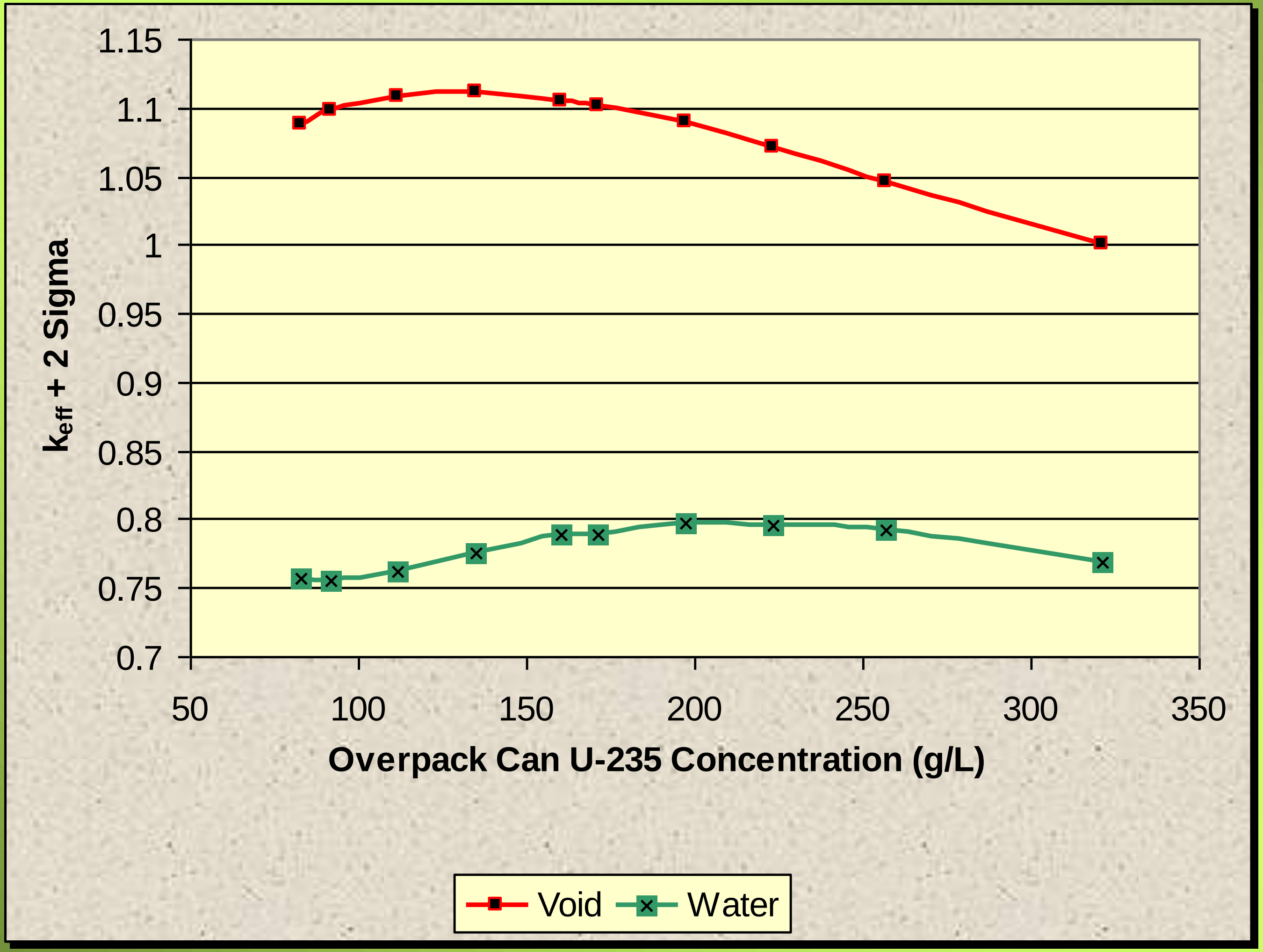
- Light Blue: Fuel Region
- Dark Blue: Stainless Steel
- Green: Fill Material
- Yellow: Lead
- Magenta: Water

- Cask ~51” Inside Diam.
- 16 Fuel Cans per Insert
- Four Tiers of Inserts/Fuel



Results of Flooded vs Drained Cask

k_{eff} vs. Fuel U-235 Concentration (g/L)



Neutron Absorbers?

- Interspersed strong absorbers (neutron poisons) ineffective without additional moderation
  - With drained cask, no moderation of fission neutrons between interacting fuel cans to allow thermal absorber effectiveness
- Placement of absorbers inside fuel cans amongst fuel is not practical
  - Preference not to remove fuel can lids
  - Difficulty in ensuring effective poison dispersal
- General preference to avoid crediting strong neutron absorbers

Polyethylene or Concrete Fill

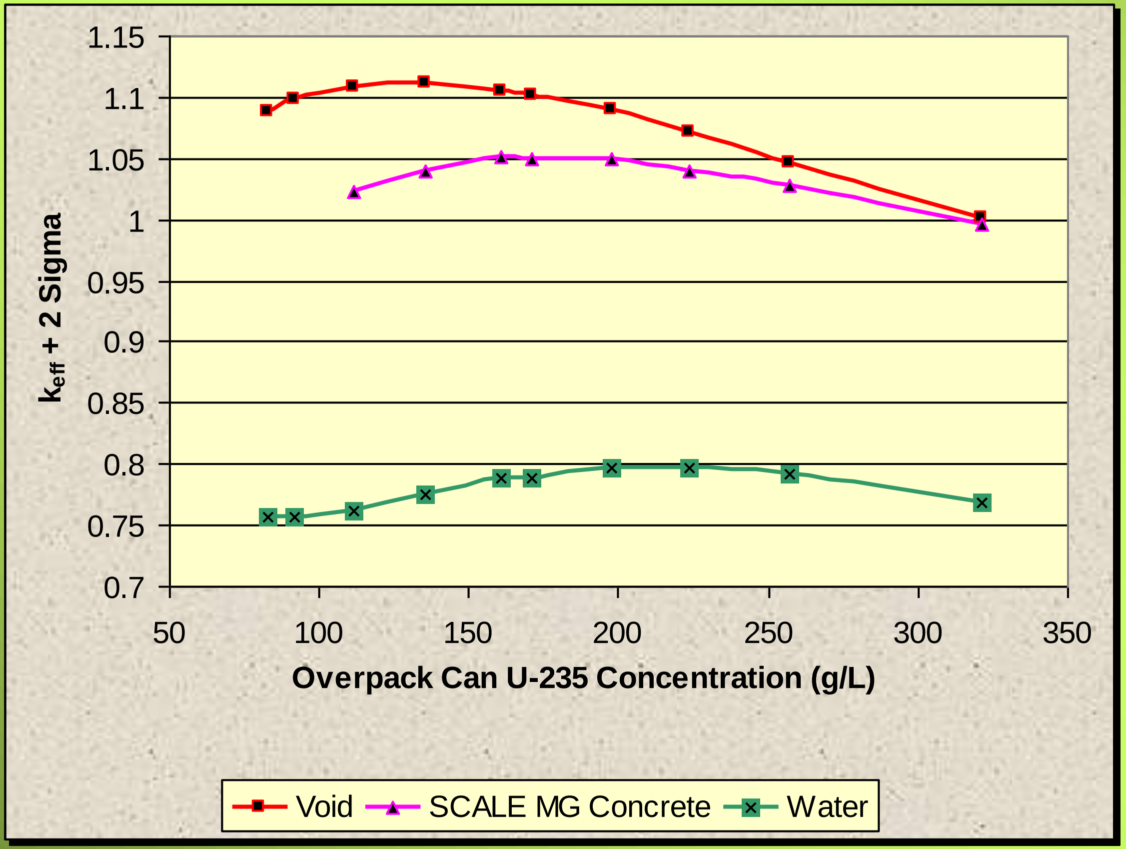
Polyethylene:

- High H density
- Low melting temperature
- Combustible

Concrete:

Low H density

Strong and Stable/Durable



Shieldwerx SWX-277 Fill Material

(Field-Castable Heat Resistant Shielding)

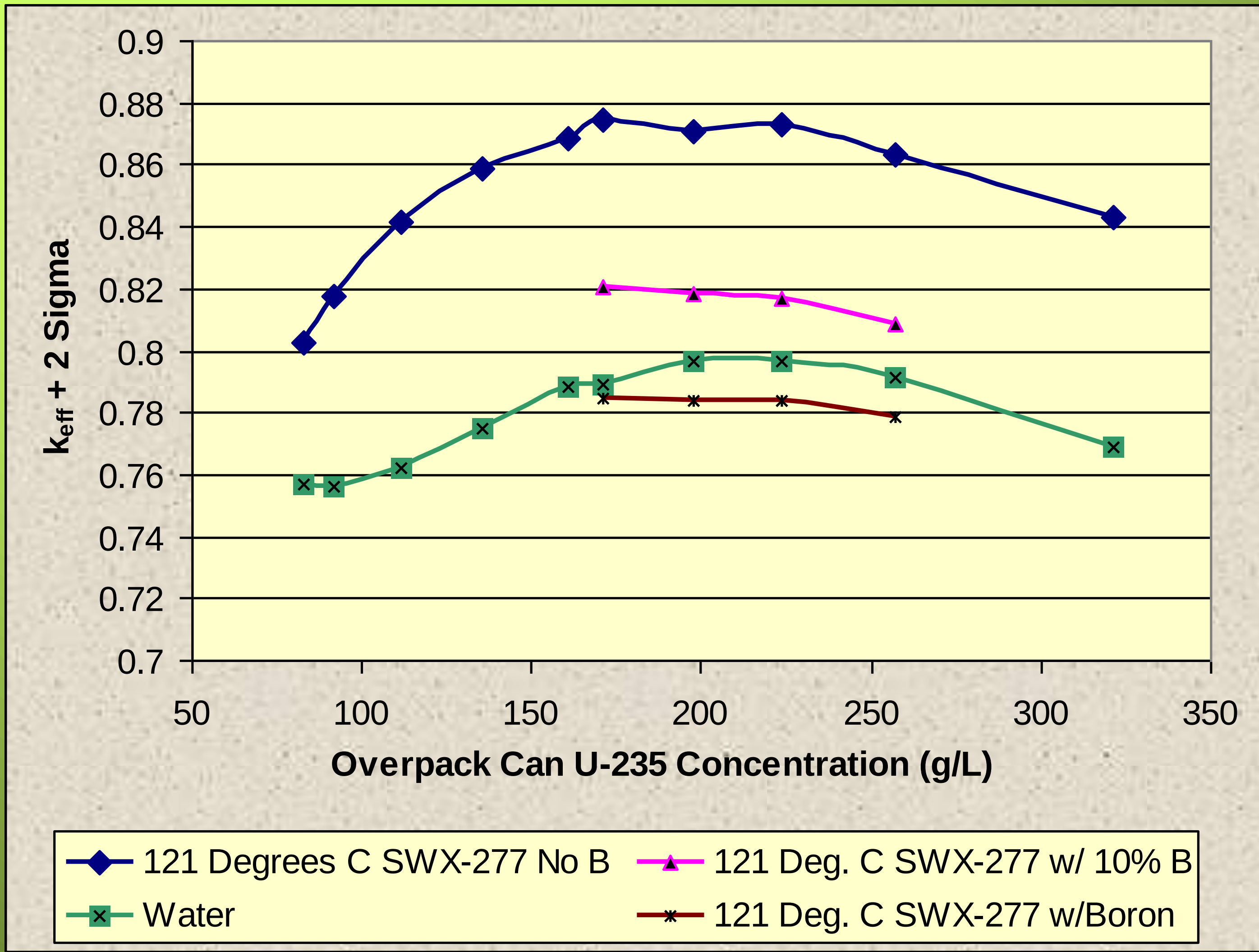
- Solid concrete-like material with high hydrogen content aggregate
- Non-combustible, rather low thermal conductivity
- Lower bulk density and strength than concrete
- Borated with natural B (nominally 1.56 weight percent)
- In use in DOT approved ES-3100 Type B Container
- Calculations:
  - With and without boron
  - Conservative H quantity (no free [pore]) water)
    - Conservatively low bulk density
    - Conservative temperature

Fill Material Hydrogen Density ($atoms/cm^3$)

Polyethylene	~8.0×10^{22}
Water	6.7×10^{22}
Shieldwerx SWX-277	~3.4×10^{22}
Concrete	~1.0×10^{22}

SWX-277 Results

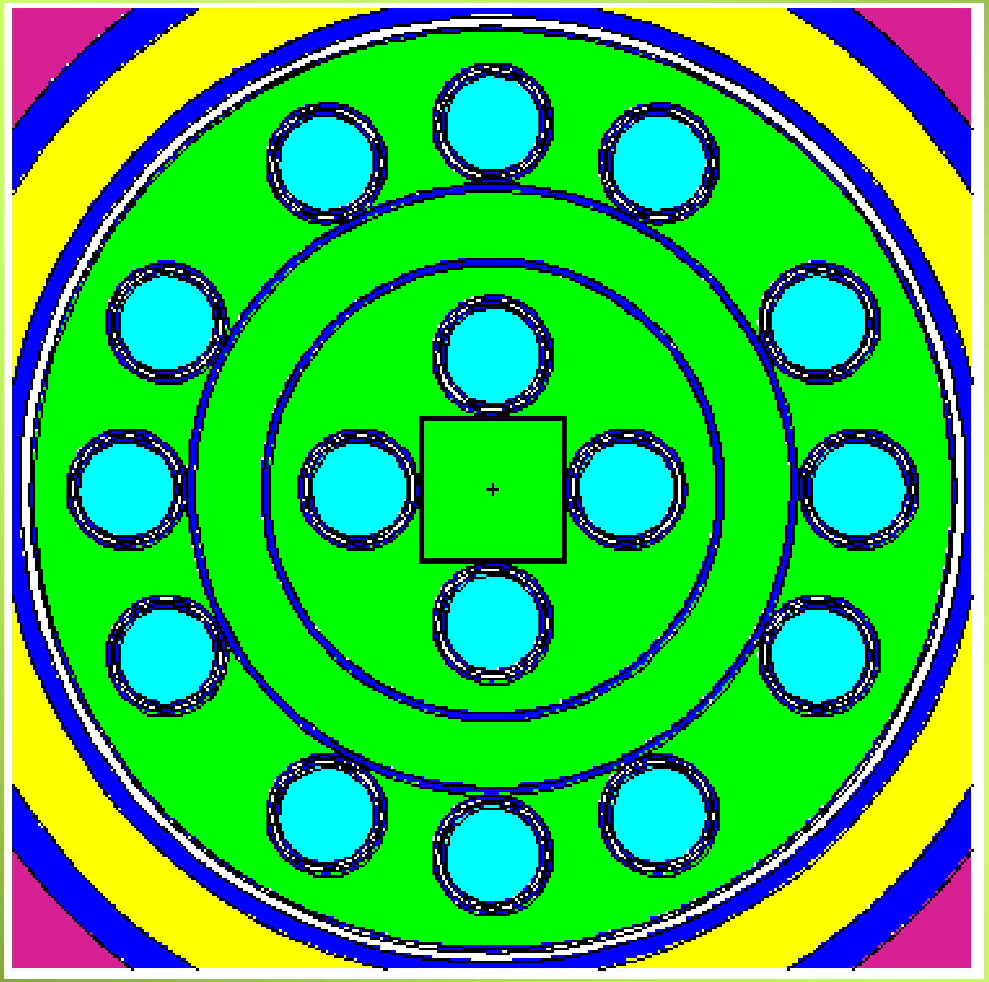
Conservative Normal Condition Composition



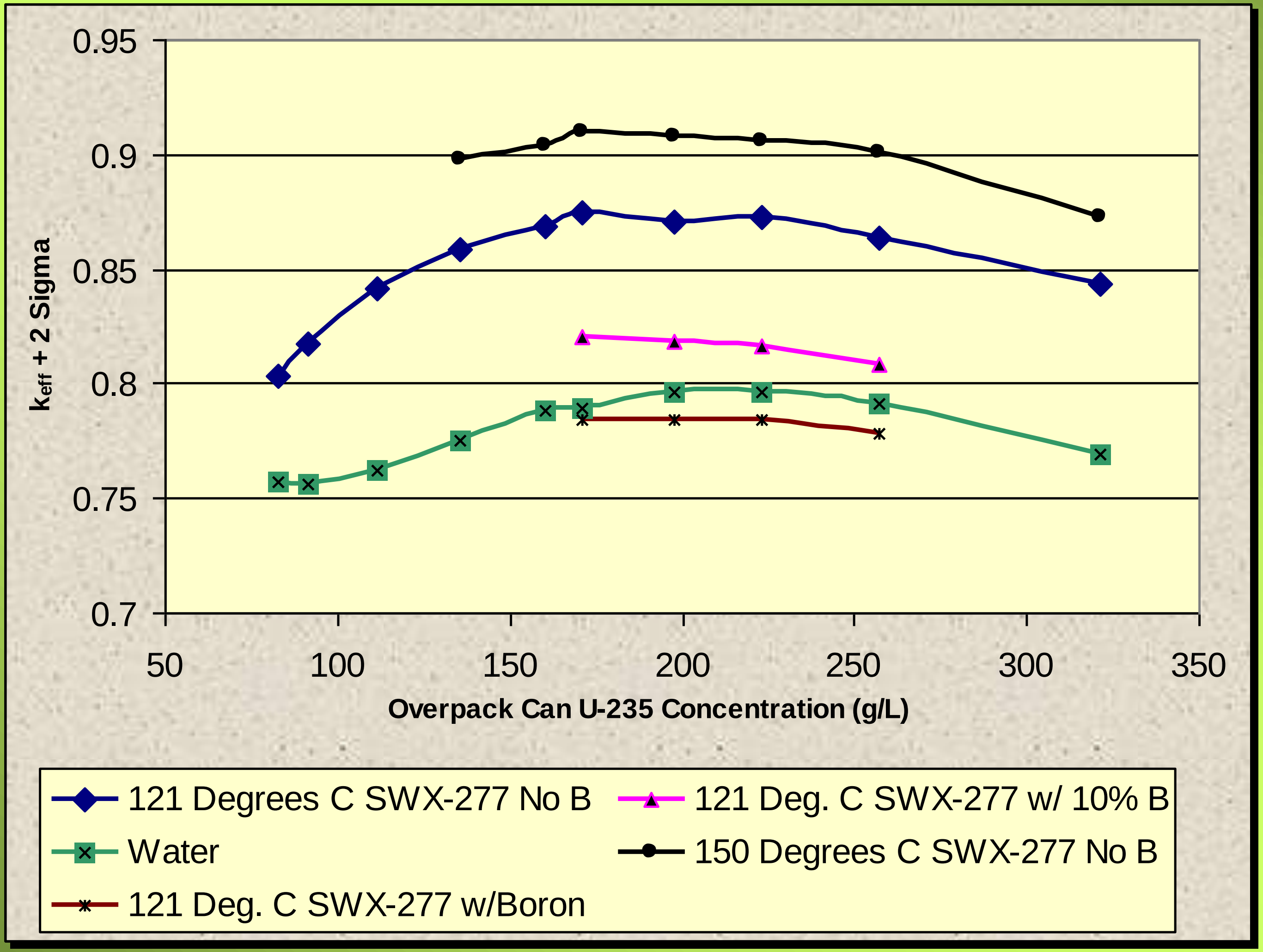
SWX-277 Upset Conditions

- Dehydration with elevated temperature results in H loss
  - Some loss over ~100 º C
  - Significant loss at ~230 º C
  - Requires significant time at elevated temperature for H loss
- Therefore, need for thermal/fire analyses and estimates on resulting H loss
- Drop mechanical damage

Model Cross Section

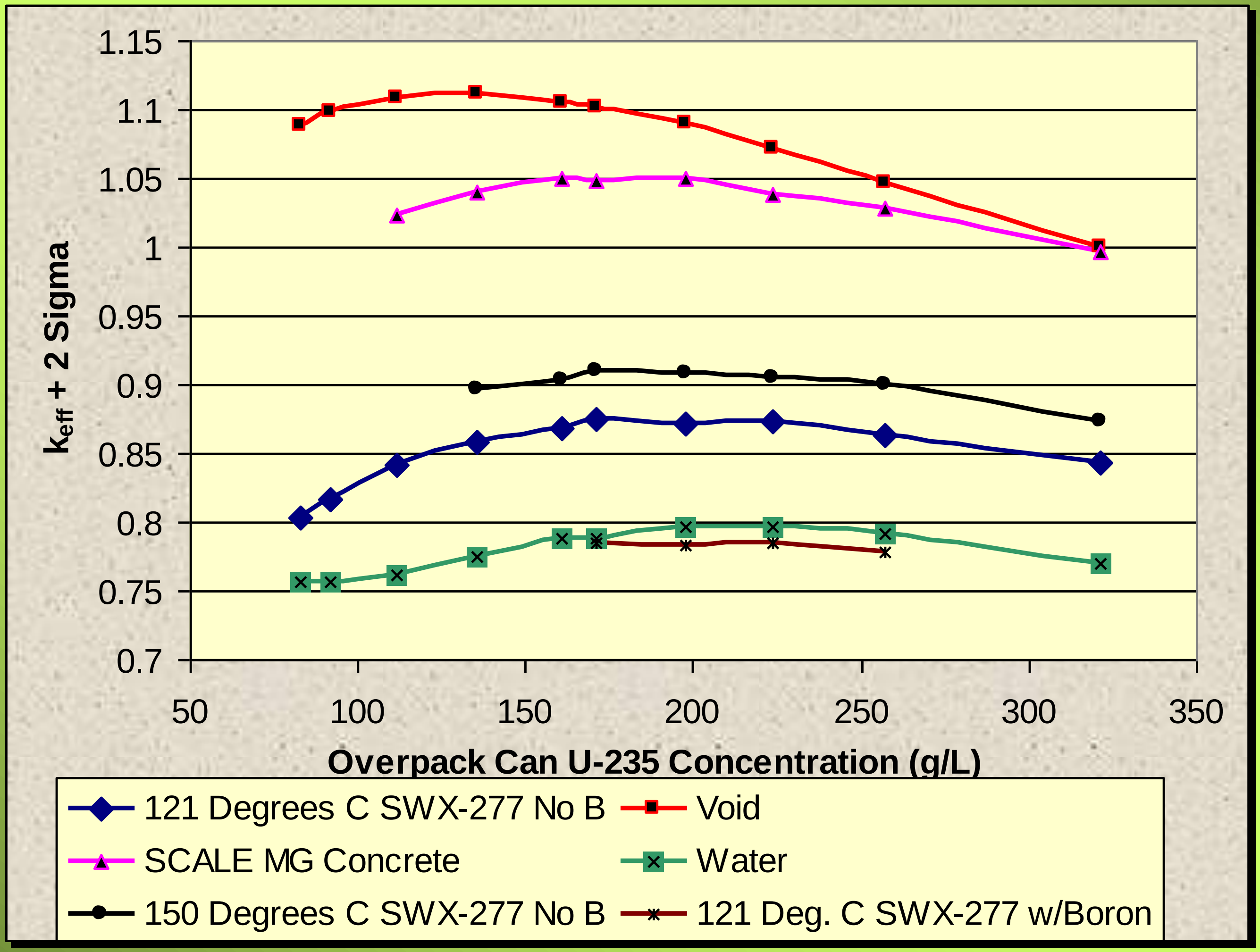


Elevated Temperature SWX-277 Results



Results Comparison

k_{eff} vs. Fuel Can U-235 Concentration (g/L)



Design Issues

Practical concerns and constraints:

- Lower strength than concrete
- Heat Transfer
- QA sampling and testing to verify required bulk density and lack of voids
- Pumping/transfer difficulty

Conclusion

- Effective isolation/interaction reduction for this application
- Neutron poison not credited
  - Simplifies QA, testing, Standards compliance
- Neutron poison present to provide defense-in-depth
- Stable, durable material that met all design requirements of this application