Metakaolin-based Geopolymer as Filler Material for Dual Purpose Canisters (DPCs)

Presentation at Geopolymer Camp

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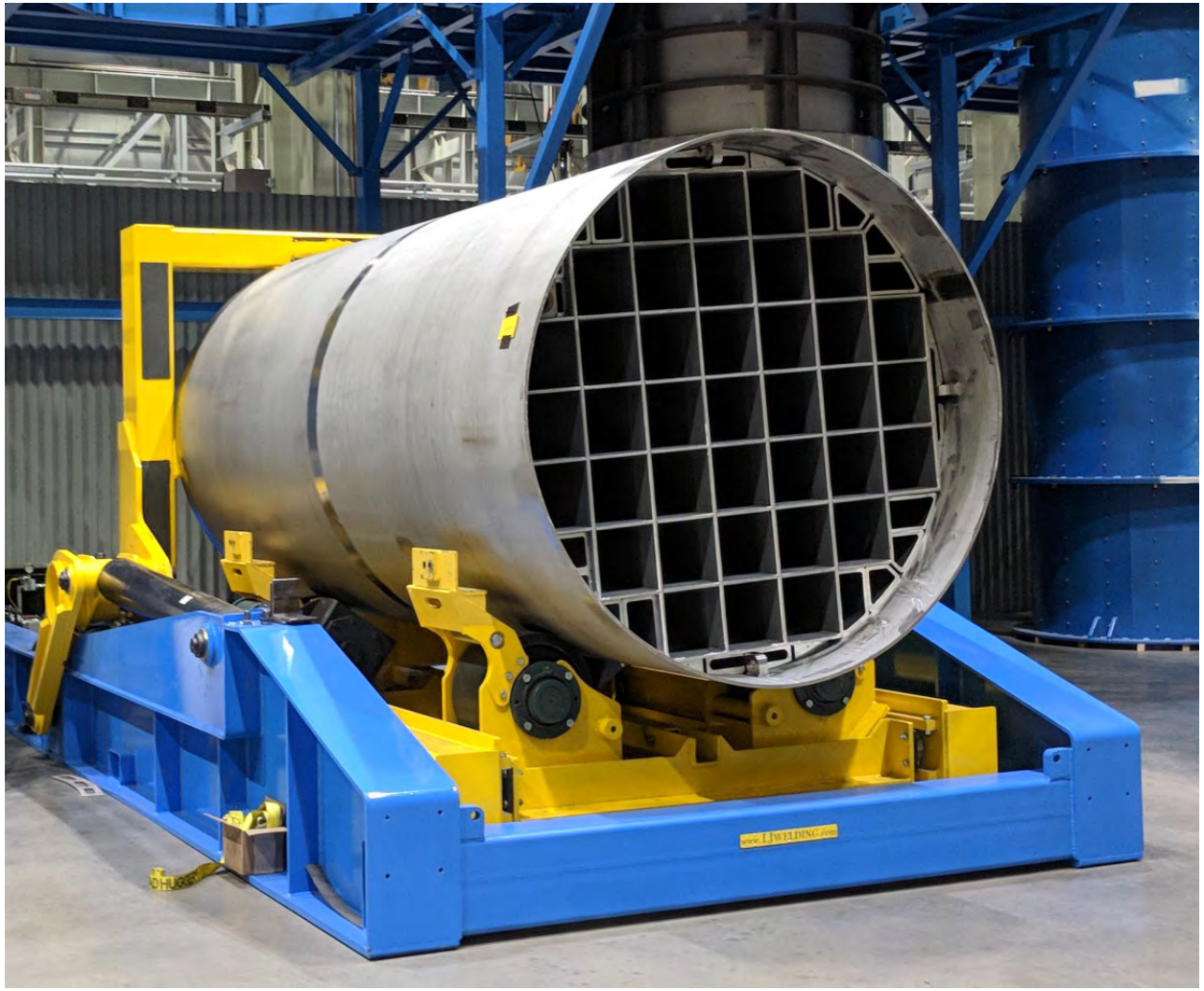
Dual Purpose Canisters (DPC)



The Dual-Purpose Canister (DPC) was conceptualized by the U.S. Department of Energy as a single versatile package suitable for on-site storage, transport, and permanent disposal in a future repository of spent nuclear fuel (SNF)

Why the DPC filler material is needed

- During storage and disposal SNF is still capable of generating dangerous amount of heat in case of the water intrusion
  - Hydrogen in water acts as a "moderator", causing elastic scattering/slowing down of the neutrons, which at this point are much more likely to start nuclear fission reaction
- The filler material is something that fills the voids between SNF elements so water cannot enter
- Ideally, the filler material should perform this function for hundreds (thousands?) of years

Why Geopolymer?

BECQ
RADIATION SHIELDING

DPC Filler requirements:

- **Criticality avoidance – minimize elastic scattering of neutrons**
  - Provide moderator displacement
  - Neutron absorption capability if needed
  - Minimize water, organic and carbonaceous constituents in filler
  - Capacity to fill greater than 60% of the canister free volume (e.g., complete filling with less than 40% porosity)
  - Fill material does not compact by more than 10% of its initial volume

Geopolymer properties:

- Water absorption: < 3 % (ASTM C 642-97)
- Volume of permeable voids: < 20 % (ASTM C 642-97)
- The principal (~90 Wt. %) elemental constituents of geopolymer binder: Si, O, Al, Na and/or K with possible B (absorber)
- Total amount of water in the mix will be kept below 20 Wt. % with part of it being lost after the cure completion
- Volume of permeable voids: < 20 % (ASTM C 642-97)
- Shrinkage during setting: negligible (ASTM C 157)

Why Geopolymer?

DPC Filler requirements:

- **Heat Transfer Properties**
  - Promote heat transfer from the fuel during handling and after disposal
- **Stability Properties**
  - Thermal stability and expansivity
  - Chemical stability (e.g., low solubility, low reactivity)
  - Radiation stability
  - Chemically compatible with cladding, fuel, neutron absorbers, fuel baskets, and other materials within canister
  - Limited gas generation (radiolytic, or on contact with ground water)

Geopolymer properties:

- Thermal conductivity > 1.30 W/m*K
- Heat conductive fillers (copper fiber)?

- CTE < 5 $\times 10^{-6}$ /°C
- Leaching in water, after 180 days: TBD
- Water absorption: < 3 % (ASTM C 642-97)
- Hydraulic permeability: < 10^{-10} m/s.
- Freeze-thaw: mass loss < 0.1 % (ASTM 4842), strength loss <5 % after 180 cycles (this becomes important after multi-year storage and cooling down of the cask

Why Geopolymer?

DPC Filler requirements:

- **Homogeneity and Rheological Properties**
  - Homogeneous and consistent batches
  - Good rheological properties (e.g., setting time, viscosity) to ensure proper filling
  - Wetting behavior for fuel and canister materials
- **Weight and Radiation Shielding**
  - Fill material doesn't add excessively to canister weight
  - Good radiation shielding properties
- **Operational Considerations**
  - Able to place in the canister without damaging fuel or canister

Geopolymer properties:

- Set time > 6 hours – adjustable, temperature dependent
- Application viscosity < 2 Pa s
- Expected to wet SS surfaces
- Density 2,000 - 2,500 kg/m^3
- To be tested
- Pourable/pumpable

Challenges (as seen now)

- What Metakaolin to choose based on performance/ availability/ consistency?
  - To date only KaMin MetaMax was tried
- What are the practical ways to minimize open porosity and water absorption?
- How to minimize viscosity of the geopolymer binder while keeping water content low?
  - Is formulating with K instead of Na the main approach?

Thank you for your attention

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