INL-LTD--18-50287-Revision-0

Alternative Crucible Materials

May 2018

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Changing the World's Energy Future

Idaho National Laboratory

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Alternative Crucible Materials

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U.S. - ROK
Joint Fuel Cycle Studies

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Alternative Crucible Materials Outline

- BeO Crucible Overview
- HfN Coated Nb Crucible Development
- UO_2 Coating Development
- UO_2 Castable Refractory Development
  - Powder preparation
  - Binder selection
  - Mold development and testing – initial attempts
  - Mold development and testing – redesigned mold
  - Future work

BeO Crucible Overview

- BeO was originally chosen as the preferred crucible material
- Failure during distillation step

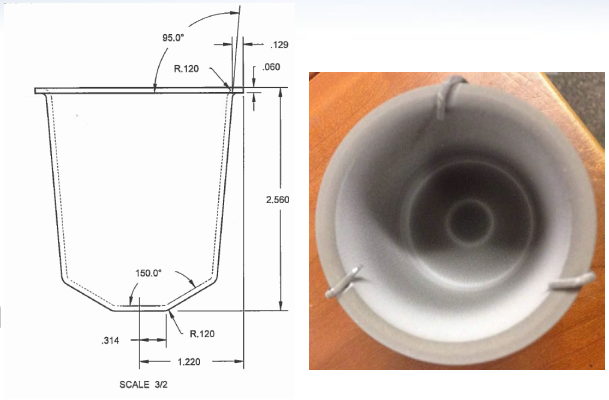
Testing in EDL

Recovery #4

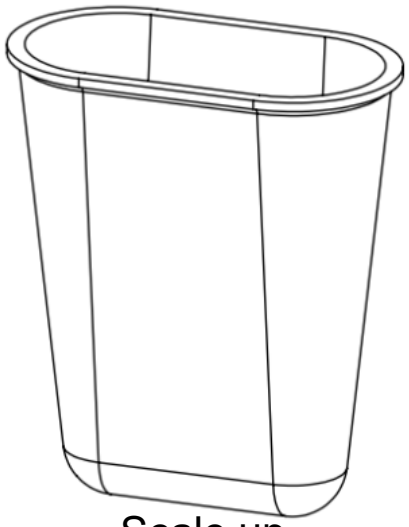
Recovery #1

HfN Coated Nb Crucible Development

- Developed a HfN coated niobium crucible that fits inside the JFCS casting furnace graphite crucible
- Procurement of scaled up niobium crucible from Metal Technology Inc. (MTI)
  - Difficult geometry to fabricate economically
  - Expected delivery week of May 21st, 2018
- HfN coating Scale up crucible
  - The Center for Thermal Spray Research at State University of New or (SUNY) is ready to begin coating testing for this geometry once they receive crucibles
  - SUNY will develop coating using iron based (stainless steel) prior to trying on Nb



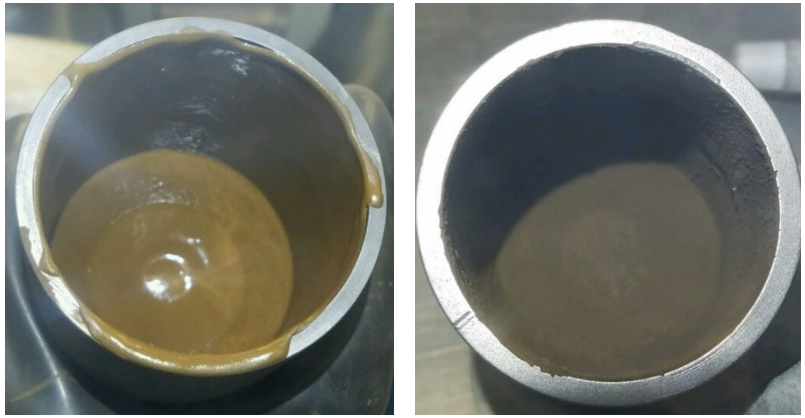
Casting Furnace



Scale up

UO_2 Coating Development

- Coating Method
  - UO_2 powder (<100 mesh)
  - 5:1 (UO_2 to LRC binder) ratio by weight
  - Mixture poured into graphite crucible and rotated until interior surface was entirely covered
- Preliminary Melt Testing
  - Uranium
  - U-10Zr
  - U-3RE



Coated crucible before drying and after drying

Crucible coating after uranium melt testing

UO_2 Castable Refractory Development

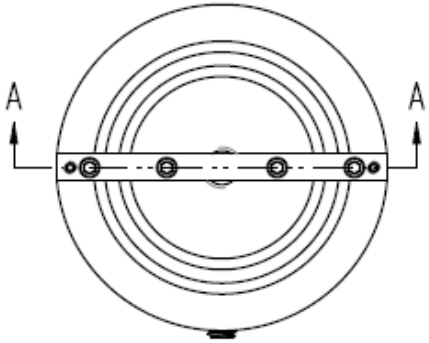
- Powder preparation
  - Feedstock: 5/8 inch (16mm) diameter pellets
  - Manual rough crush
  - Jar-milling (tumbling)
    - Sieve homogeneous sample
    - Target particle size distribution
      - Based on commercially available ZrO_2 castable refractory

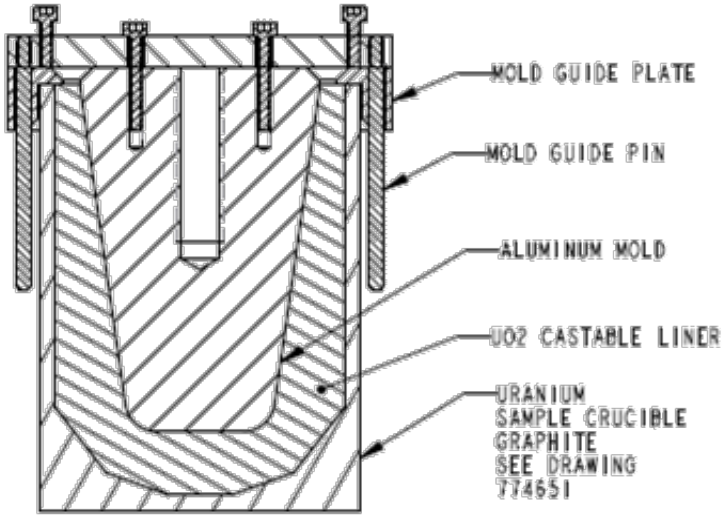
UO_2 Castable Refractory Development

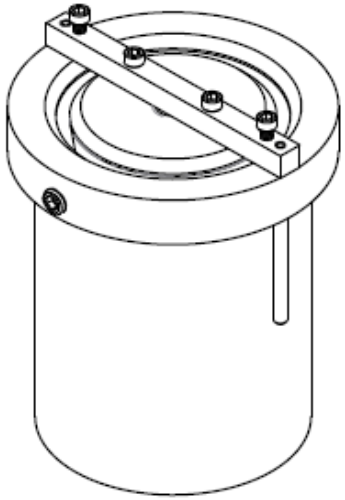
- Binder selection
  - Initial testing with two binders from ZYP Coatings
    - LRC
    - Gel-P
  - UO_2 powder was mixed with binder in nickel crucibles and allowed to harden
  - LRC binder was selected for further testing
    - Less binder required to fluidize mixture

UO_2 Castable Refractory Development

- Mold development
  - Molds were developed to cast UO_2 liners into graphite crucibles
    - Small size
      - Casting furnace crucible
    - Medium size
      - Uranium sampling crucible

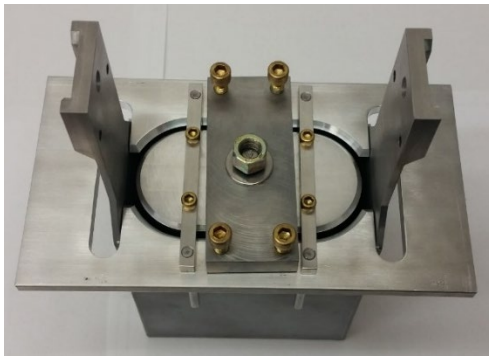


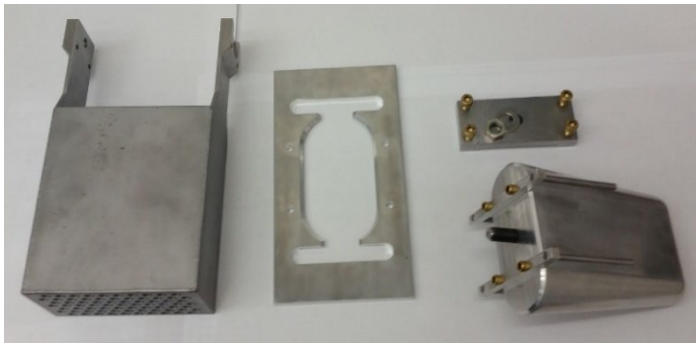


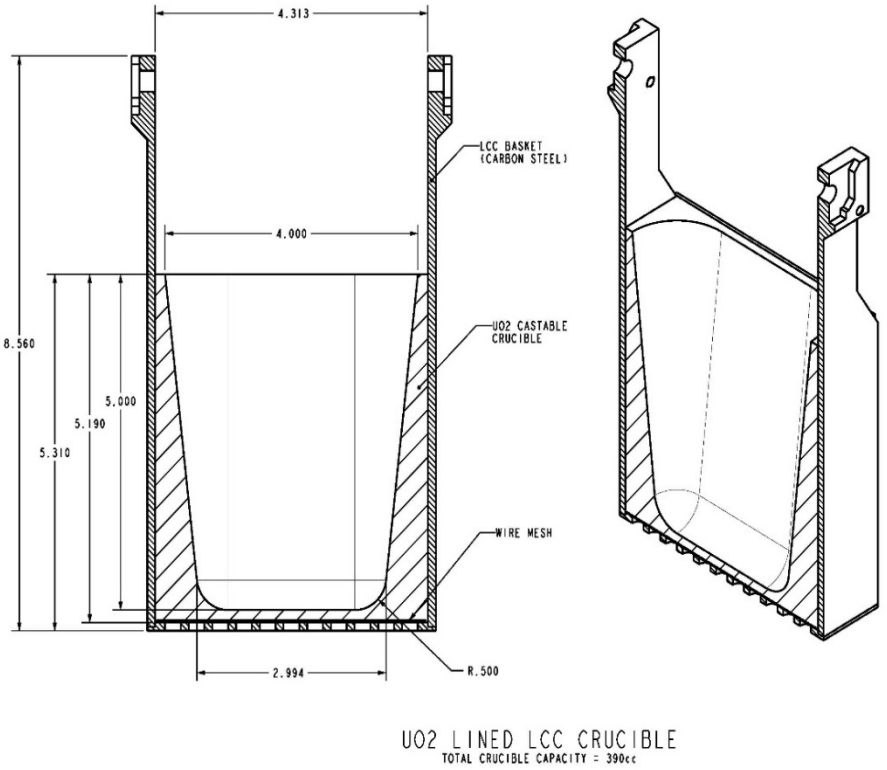


UO_2 Castable Refractory Development

- Mold development
  - Mold developed for casting UO_2 liners into a steel basket



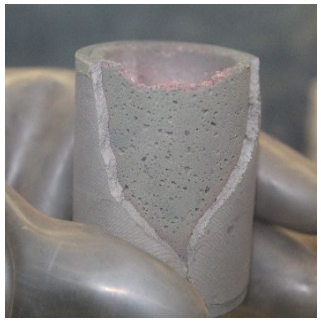


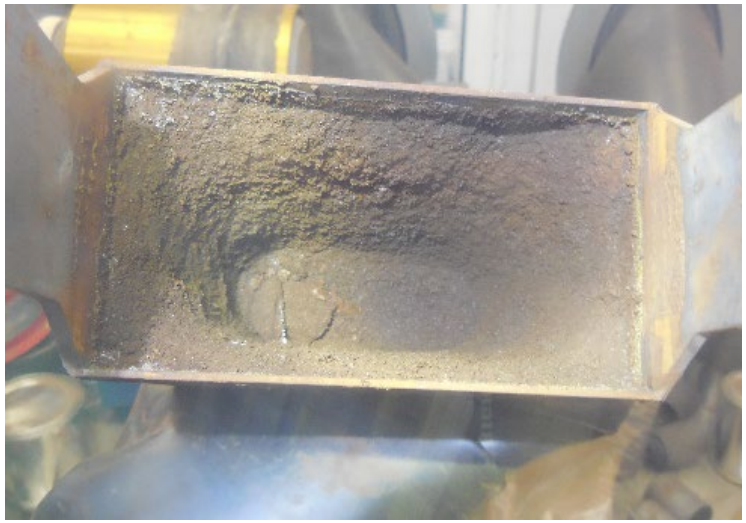


UO2 LINED LCC CRUCIBLE
TOTAL CRUCIBLE CAPACITY = 390cc

UO_2 Castable Refractory Development

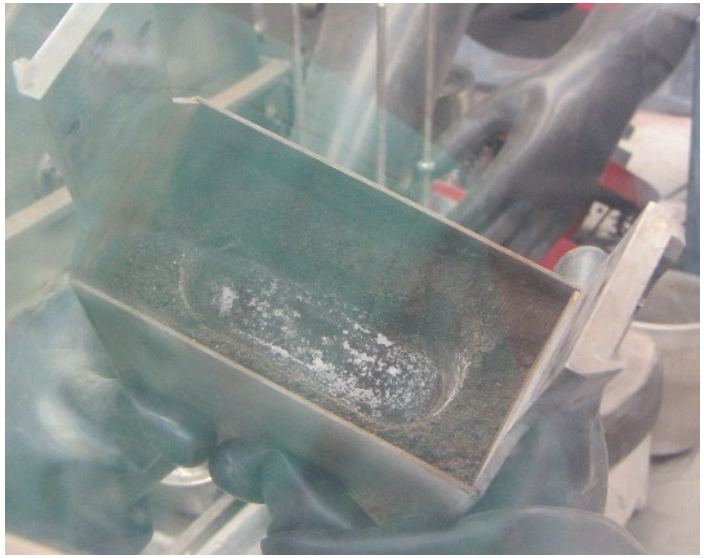
- Mold development and testing
  - Small and medium crucible liners cast using LRC binder were mostly successful
    - Cracked graphite during firing
  - Large crucible liner did not adequately dry and harden in a reasonable amount of time.





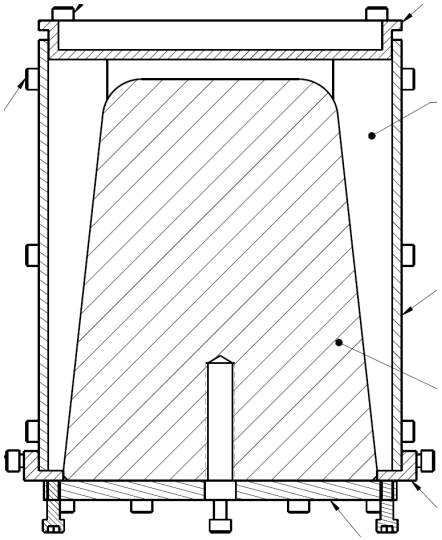
UO_2 Castable Refractory Development

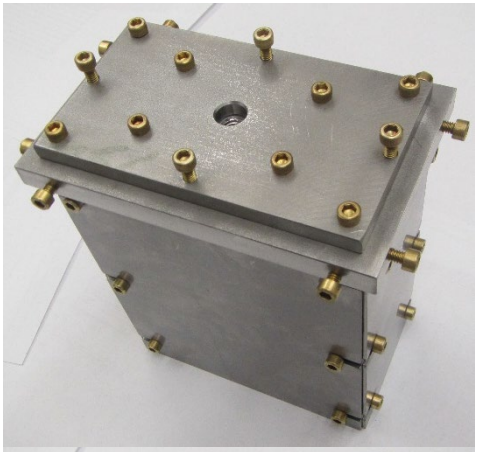
- Issues with binder discovered in testing
  - New binder selection
    - LRC binder did not dry in a reasonable amount of time
    - Secar 71®
  - Attempts on Small and Medium crucibles were successful
    - no cracked graphite
  - Large mold was not able to be pushed sufficiently into the refractory



UO_2 Castable Refractory Development

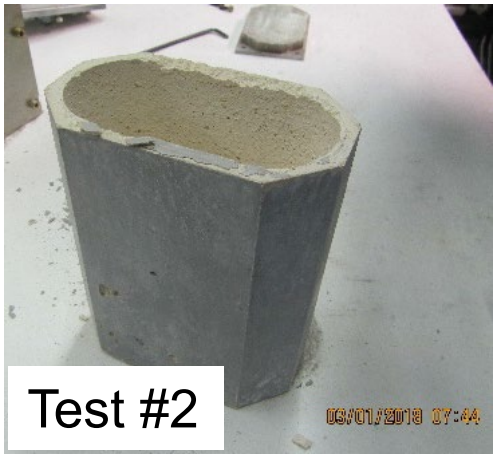
- Redesigned mold for large crucibles
  - Creates standalone crucible
  - Form crucible upside-down
  - Refractory mix is poured into the mold
    - no pushing mold into mixture
  - 48 hours cure
    - Inner mold piece is removed
  - Refractory is heated to remove excess moisture
  - Outer form pieces are removed

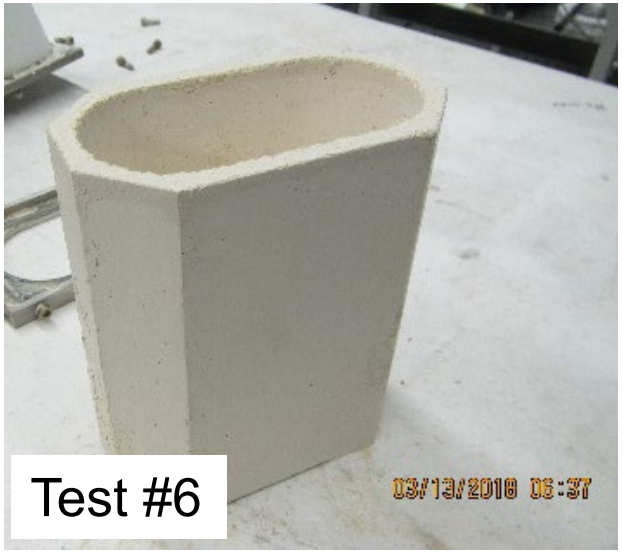




UO_2 Castable Refractory Development

- Redesigned mold testing
  - Testing with ZrO_2 segregate material
    - Seven tests
    - Investigated mold release agents
    - Developed methods to improve inside surface finish
    - Refined binder and water ratios
    - Developed improved methods to mix refractory in glovebox





UO_2 Castable Refractory Development

- Redesigned mold testing
  - At this time we have formed two large crucibles
  - pending high temperature sintering/firing (1600°C)

UO_2 Castable Refractory Development

- Future work for UO_2 crucible development
  - High temperature sintere/fire large crucibles
  - Melt uranium metal in UO_2 crucibles to study behavior
  - Melt salts in UO_2 crucibles to study behavior with the refractory
  - Melt other materials (rare earth, etc.) to study interaction with the UO_2 refractory.
  - Deploy UO_2 refractory for use in IRT equipment

- Plan for future IRT material recoveries
  - Fabricate hardware for three options
    - BeO scrape crucible (without drain holes)
    - HfN coated Nb crucible
    - UO_2 crucible