National Nuclear Security Administration (NNSA)

Defense Nuclear Nonproliferation (DNN)

RERTR

U.S. High Performance Research Reactor (USHPRR) HFIR Silicide Fabrication Update

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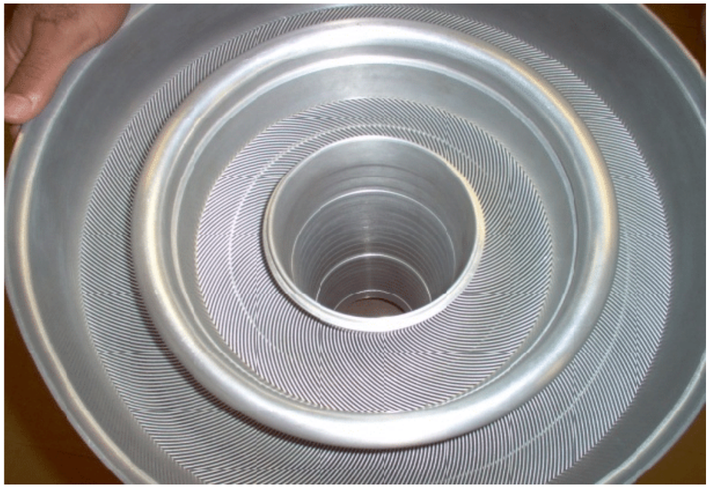
Background

- NA-23's USHPRR Convert Project will convert HFIR U_3O_8 HEU fuel to U_3Si_2 HALEU dispersion fuel

- Fuel is developed by a series of reactor tests: single plates for proof of concept then single and multiple plates and element tests for fuel qualification.

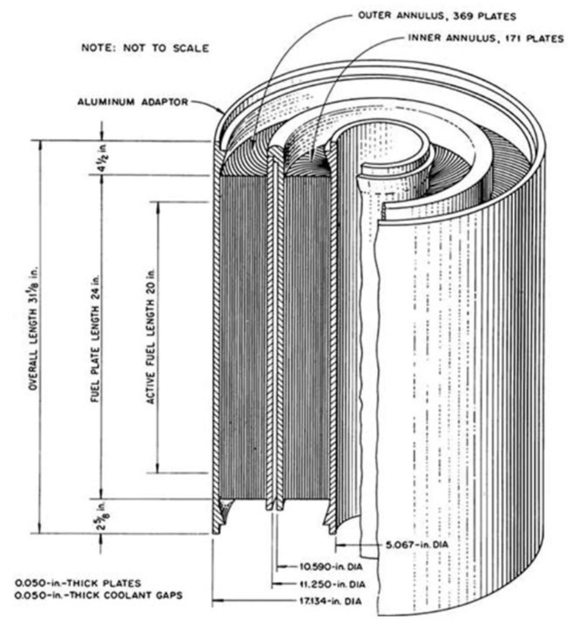
HFIR Reactor Fuel Core

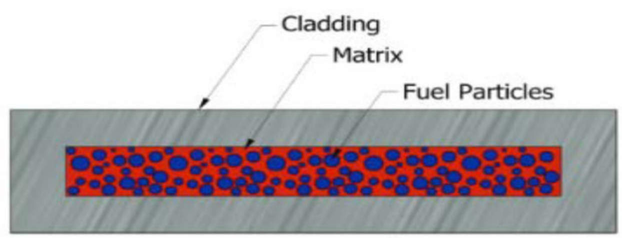


Approximately 550 fueled plates

High Flux Isotope Reactor (HFIR)

- Fuel Core
    - Inner Fuel Element, IFE, 171 plates
    - Outer Fuel Element, OFE, 369 plates
- About 7 cores per year
- The current HFIR HEU core uses ~9 kg of U-235
- HFIR is 500+ W/cm^2



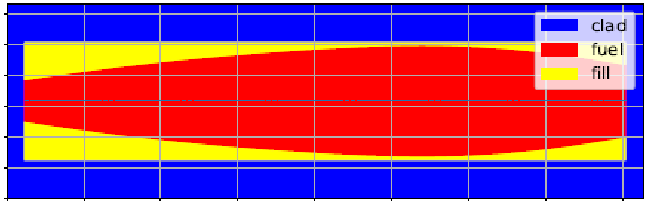


Dispersion Fuel

HFIR Proposed Designs

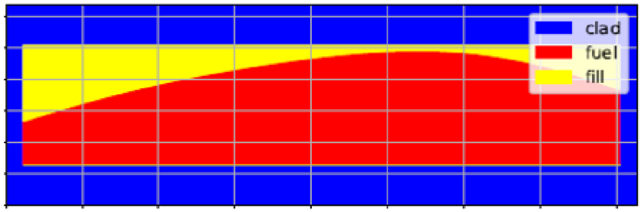
Parallel method development as risk mitigation

Centered and symmetric design



PNNL method development
Not currently fabricable at BWXT due to equipment availability and process maturity

Non-symmetric design



BWXT method development
Similar process to HEU HFIR fuel fabrication

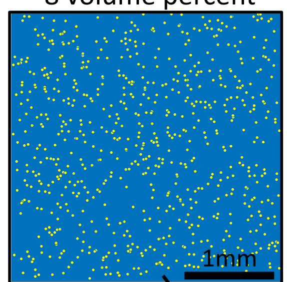
*Images obtained from Bae et. al. 2021 ORNL/TM-2020/1798 and Betzler et. al 2021 ORNL/TM-2021/1964

Manufacturing Challenges with LEU Silicide

- HEU is 92% Al – isotropic properties
- LEU is nearly 50% silicide – heterogeneous thermal properties

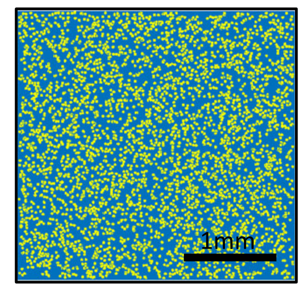
- Mechanical and thermal properties different between volume loadings
- UT signal differences

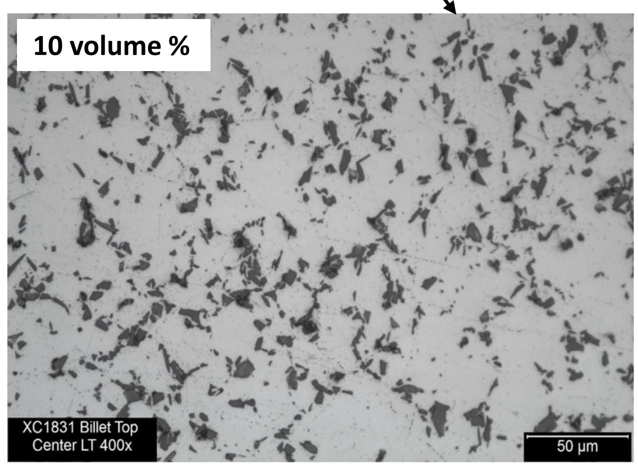
Current HEU U_3O_8
~8 volume percent

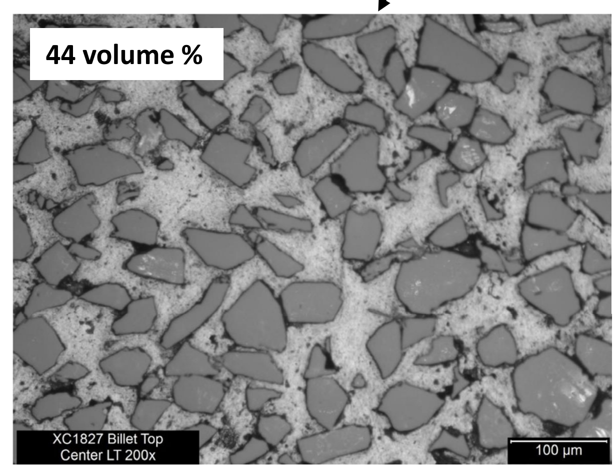


Blue: Matrix
Yellow: Fuel Particle
~30 micron

U_3Si_2 (4.8 gU/cc)
~45 volume percent

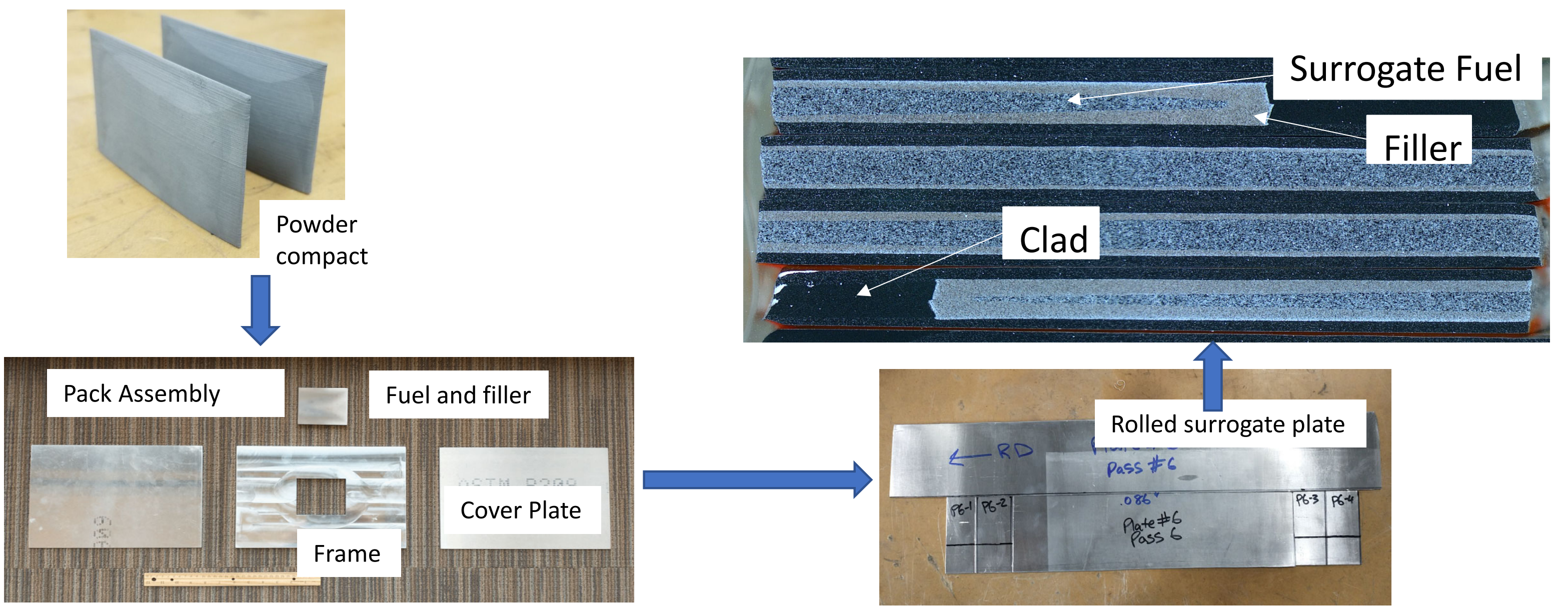




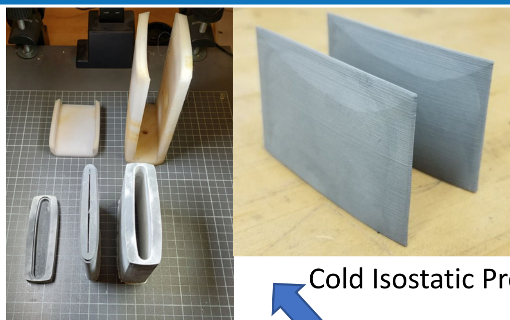


Present and Upcoming Work

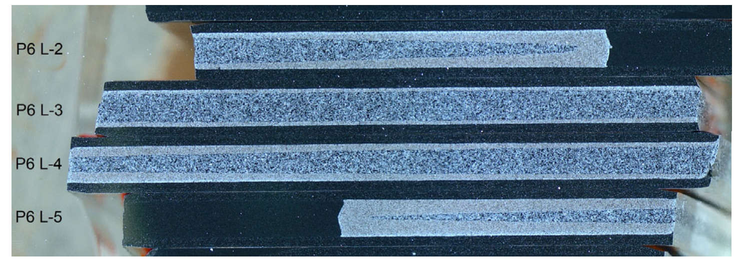
- Development of a symmetric fuel fabrication process based on traditional composite processing schemes
    - Surrogate work ongoing with upcoming transition to uranium silicide processing in FY23
    - All work is on full-sized plates
- Optimization of processes to produce a robust manufacturing process for symmetric or non-symmetric fuel design
    - Some optimization can start now, some is specific to fuel design chosen



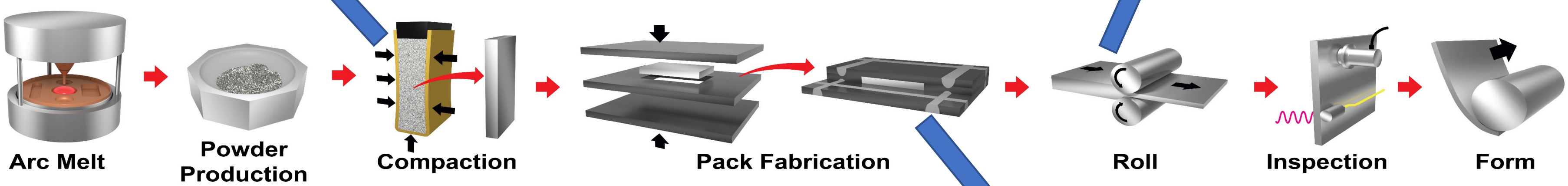
Process Flow – HFIR Dispersion Fuel



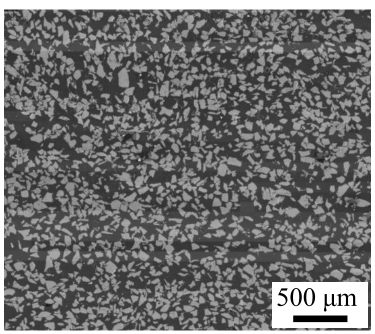
Cold Isostatic Pressing



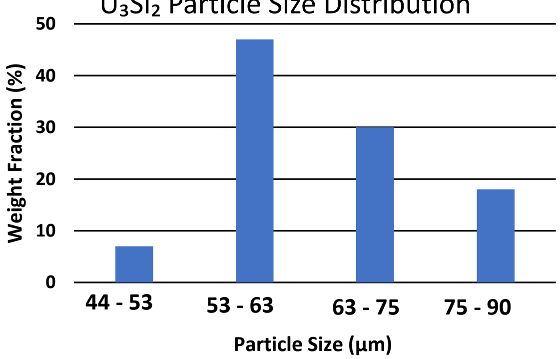
Transverse contour



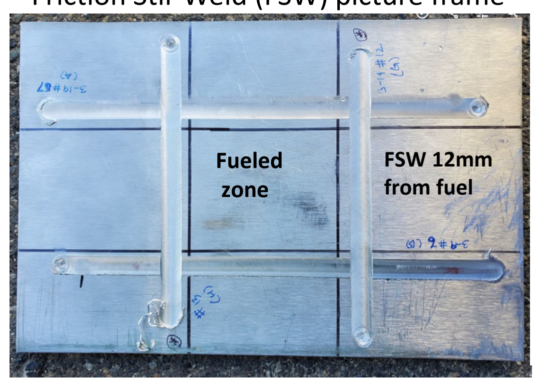
Controlled particle size distributions

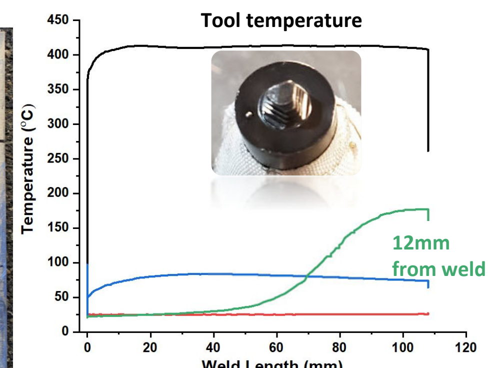


U_3Si_2 Particle Size Distribution



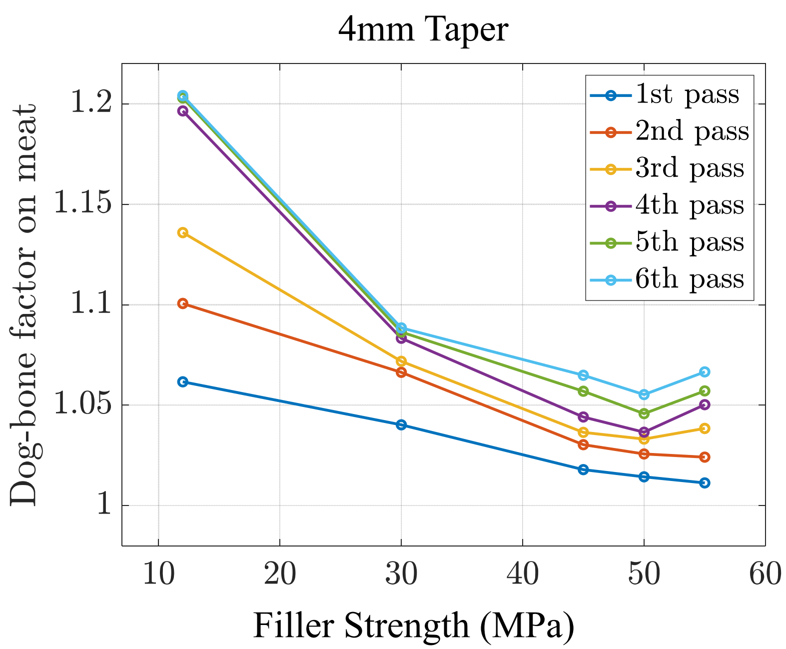
Friction Stir Weld (FSW) picture frame





Dogbone Reduction

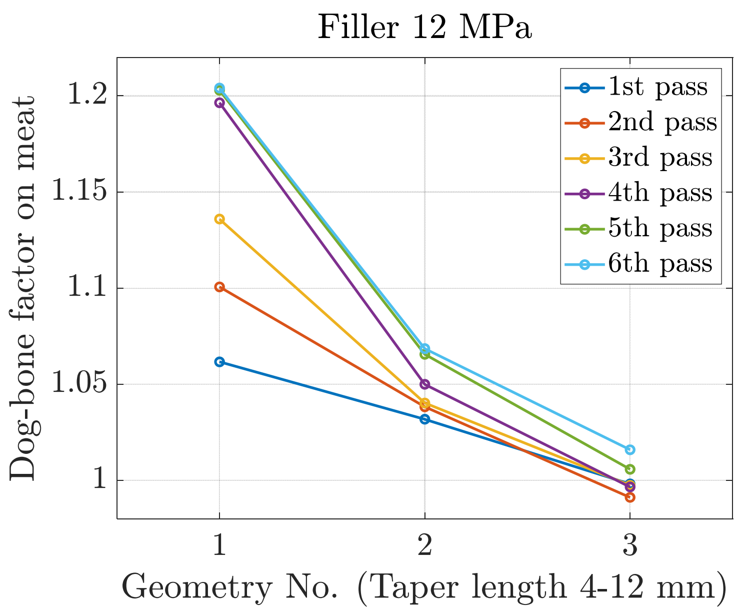
- Close matching of the filler and fuel meat flow stress reduces dogbone
- This is not feasible with traditional Al-B_4C fillers
- Additions of 10-20 vol% SiC in the Al-B_4C burnable absorber closely match the fuel meat strength



Matching filler and fuel meat flow strengths reduces dogbone defects.

Dogbone Reduction

- Pre-rolled silicide compact design can reduce dogbone by adding taper
- This is not feasible with die pressing
- Isostatic pressing can make tapers with uniform fuel compact density



The shape of the compacted powder can reduce or even eliminate the dogbone

Summary

- BWXT and Fuel Fabrication Pillar are pursuing 2 parallel development paths:
    1. Symmetric fuel geometry with traditional composite approach
    2. Non-symmetric fuel geometry with HEU HFIR approach
- Existing silicide fabrication capabilities at BWXT are subject to potential optimization through R&D
- LEU silicide designs are high vol% which causes many changes in material behavior and processing
- Symmetric fabrication process has promising results to date - look to transition to U_3Si_2-Al in FY23

Questions?