INL/CON-19-56024-Revision-0

Current Plans for Irradiation Testing of Low Enriched Uranium Silicide Fuel in Support of High Flux Isotope Reactor (HFIR) Conversion

October 2019

Irina Glagolenko

Changing the World's Energy Future

Idaho National Laboratory

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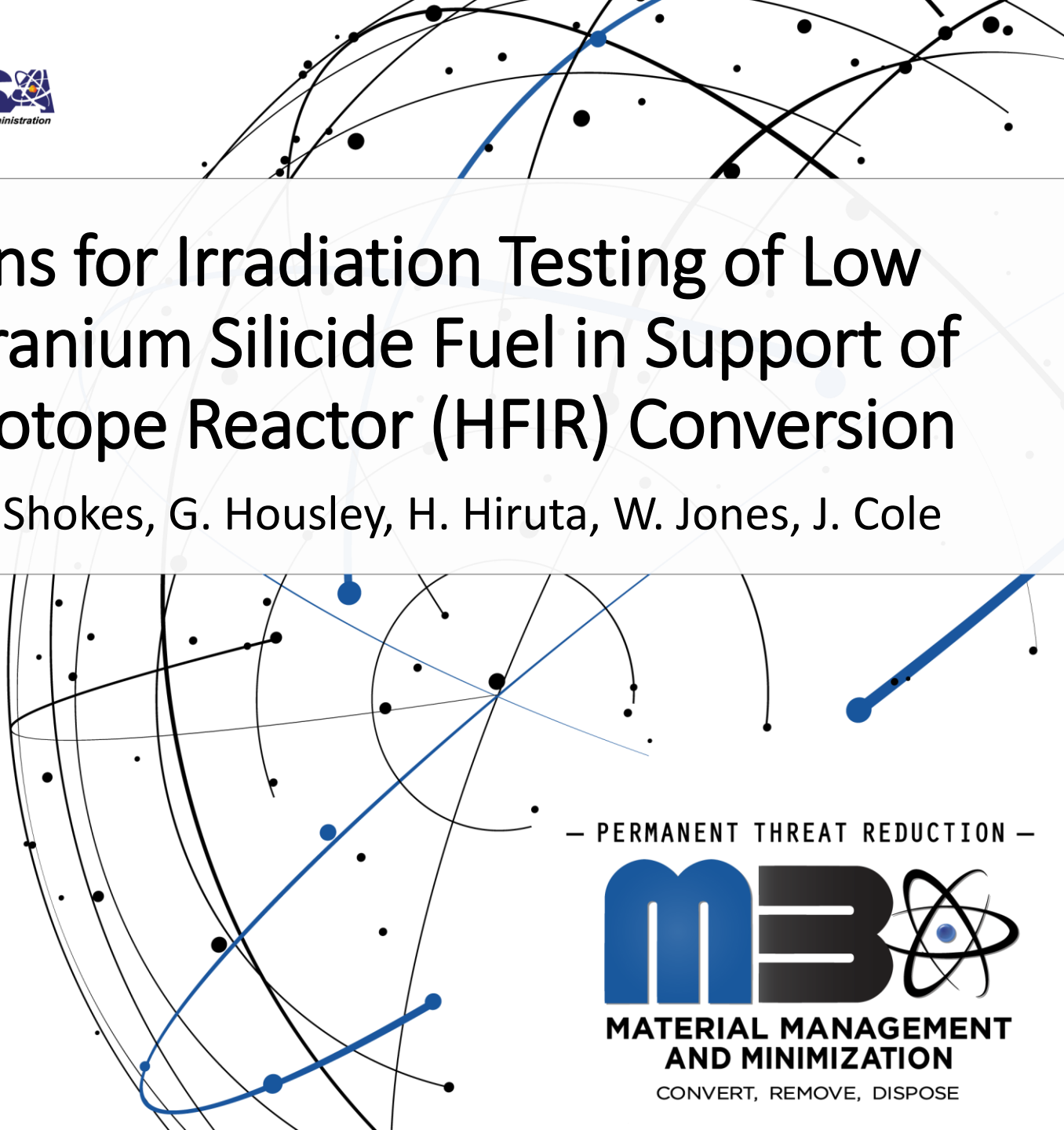
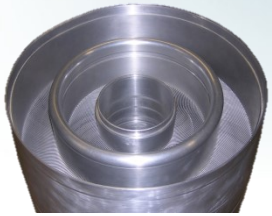
I. Glagolenko, T. Shokes, G. Housley, H. Hiruta, W. Jones, J. Cole



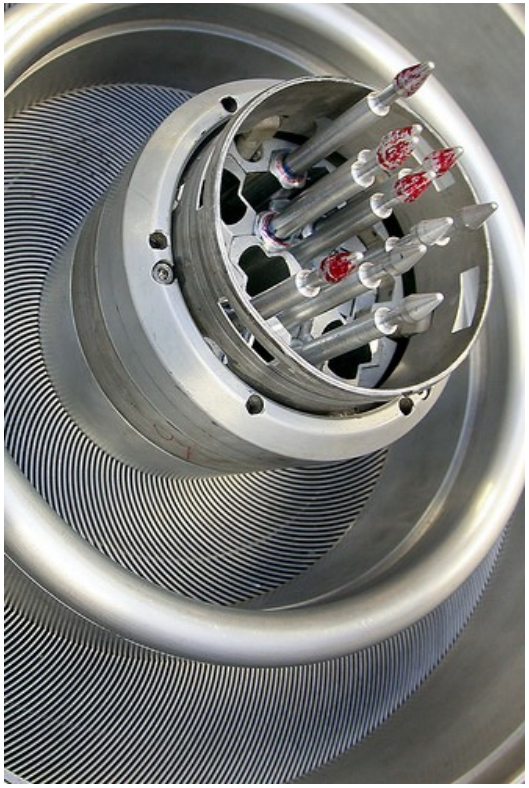
— PERMANENT THREAT REDUCTION —

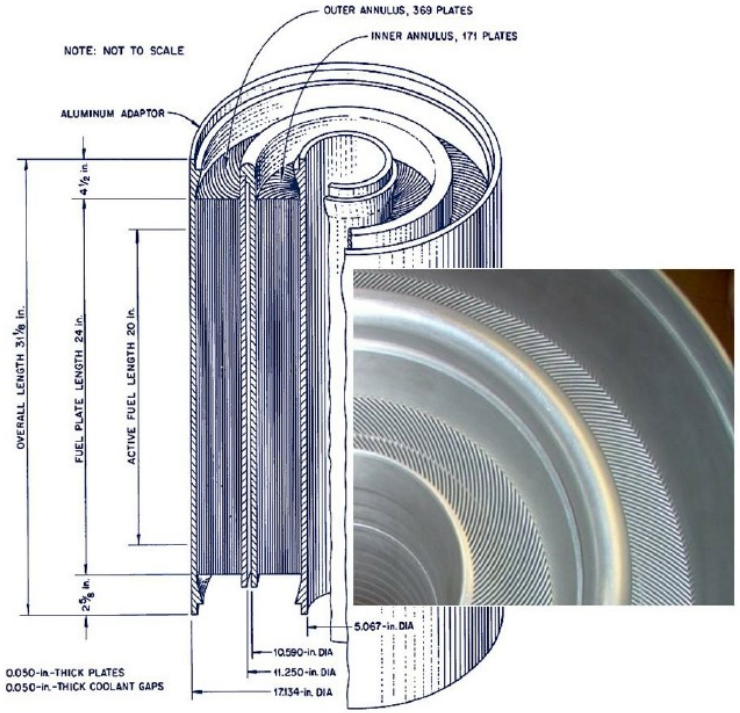
MATERIAL MANAGEMENT AND MINIMIZATION

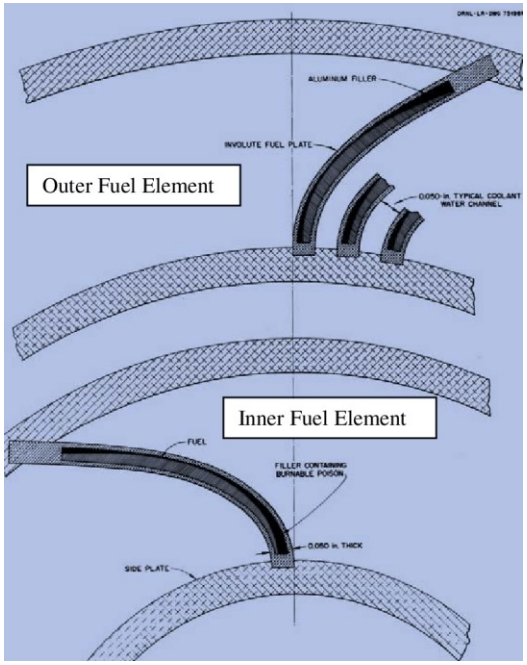
CONVERT, REMOVE, DISPOSE



Complexity and uniqueness of HFIR fuel element



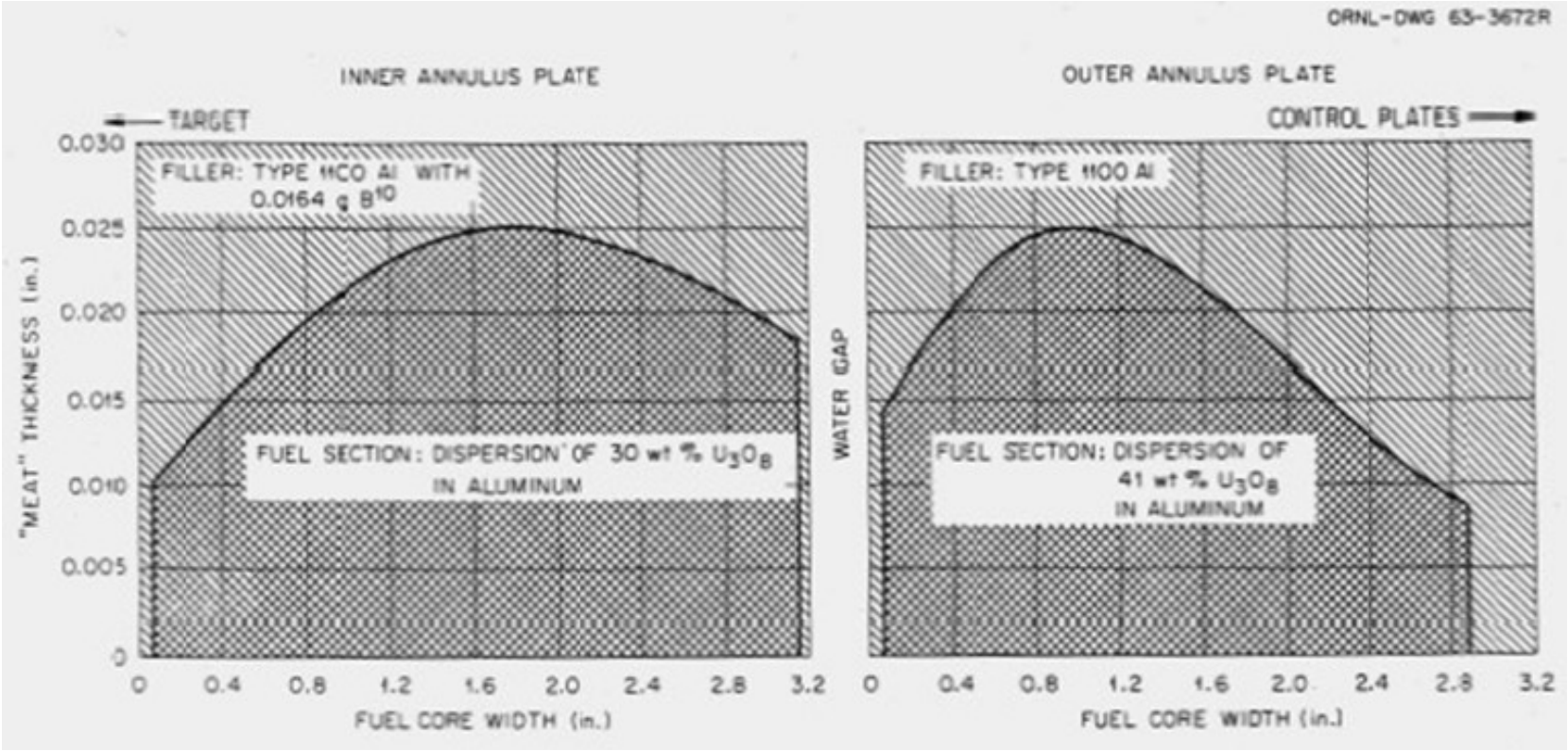




- 171 plates in IFE and 369 plates in OFE
- All plates within an element (IFE or OFE) look the same and operate pretty much in one mode
- Each hot plate is effectively surrounded by 2 other hot plates
- Channels are 50 mils thick, very narrow

Complexity of HFIR fuel plates

- Current fuel – U3O8 HEU dispersion
- Involute geometry of the plates
- Contouring of fuel meat and addition of BA for power shaping and holding off BOL reactivity



Motivation behind switching from UMo to U_3Si_2

- **HFIR fuel is unique and complex!**
  - **Main disadvantages of U-Mo monolithic**
    - challenges with making contoured U-10 Mo foil shapes and incorporating burnable absorbers – not a trivial task
    - likely delaying conversion dates
- **Search for an easier solution (mainly in fabrication space)**
  - Aware of silicide 'backup' solution to 'primary' U-7Mo dispersion in European High Power Research Reactors
  - **Main advantages of silicide**
    - Dispersion: easier to contour and incorporate burnable absorbers
    - More effective U utilization
    - Not a new fuel – silicide was previously qualified for generic use at low power (NUREG-1313) - leverage
    - High power testing of silicide in Europe (JHR reactor) plus new upcoming silicide tests – leverage
    - Reinvigoration of BWXT LEU silicide line for BR2 - leverage

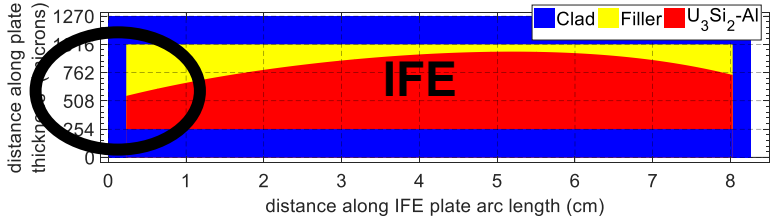
Silicide for HFIR

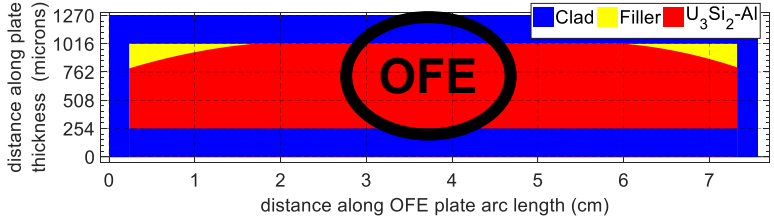
- **Silicide approach applied to HFIR**
  - relaxing some of the previously imposed USHPRR program requirements:
    - one fuel for all reactors
    - no fuel geometric changes
- **Main advantage**
  - reeling in conversion dates
- **Decision**
  - to pursue silicide conversion path (UMo is in the risk space)
- **Main enabling assumptions**
  - easy to fabricate
  - fuel performance the same as in NUREG-1313

Four ORNL silicide designs are currently on the table

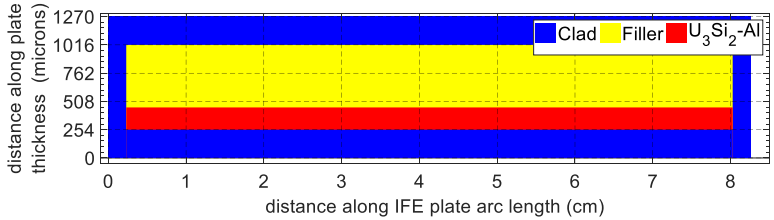
- All four have 4.8 g U/cc, slight geometric variations
- All are still complex: contoured fuel and burnable absorber are still present!
- ORNL physics group is currently working on 5.3 g U/cc designs
- Down-selection will be made in fabrication campaign, prior to testing
- Fuel Qualification Pillar is shaping fuel qualification strategy and performing scoping studies for the experiments

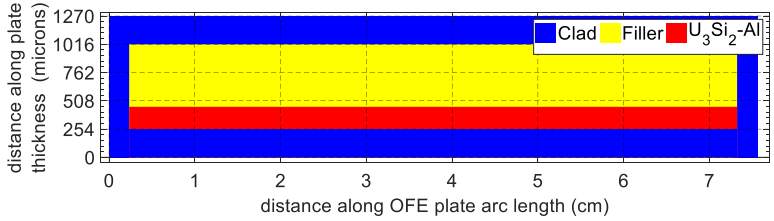
Alternative 1 silicide design





Uppermost 54.88 cm of fuel zone



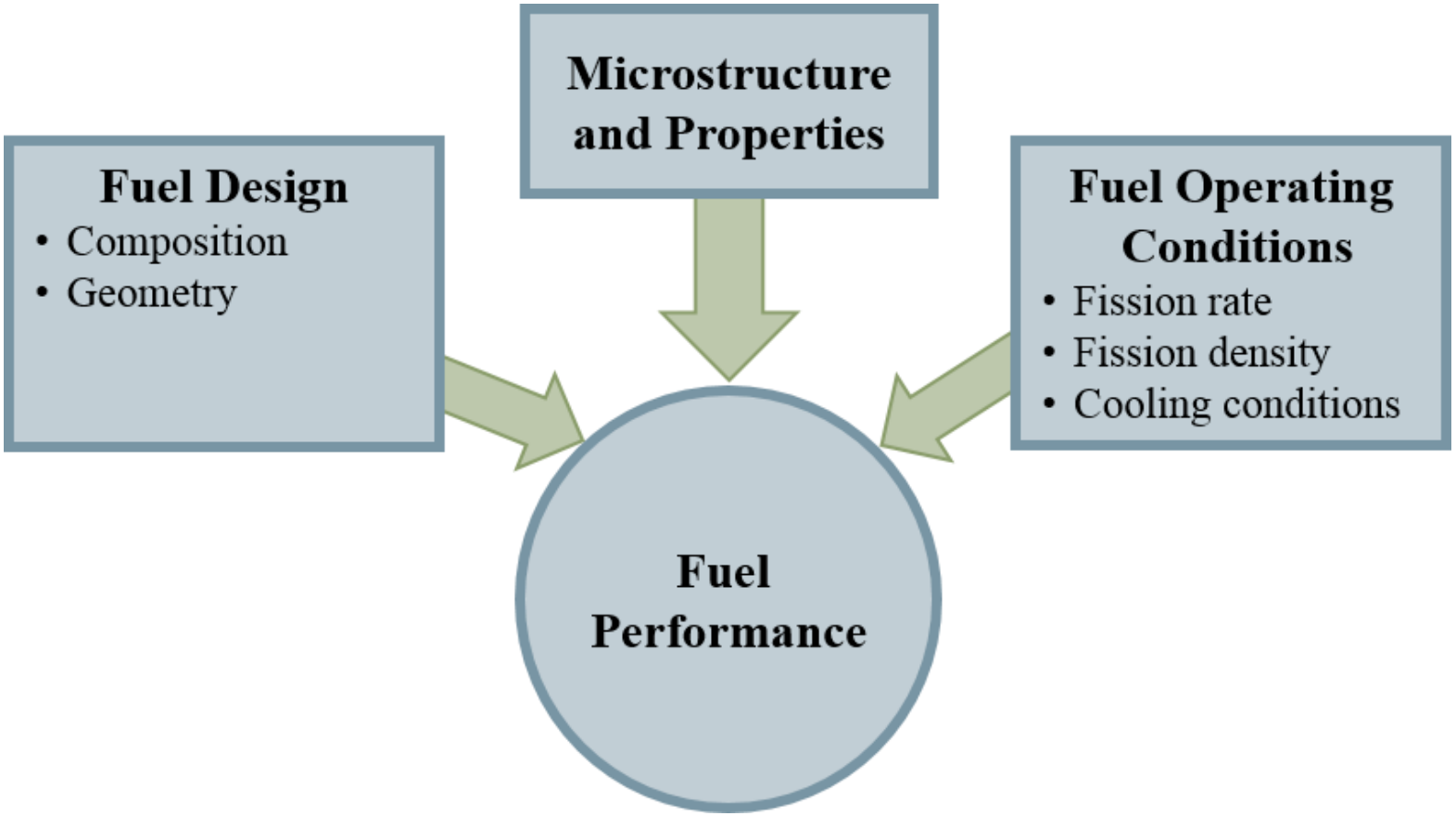


Bottommost edge of fuel zone
(axial contour profile interpolated over 1-cm zone)

	IFE	OFE
Peak power, kW/cc	~56	~31
Peak burnup, fiss/cc	~3.3 E21 (%)	~2.5 E21 (%)
Peak heat flux, W/cm2	~371	~451

Courtesy of D. Chandler (ORNL)

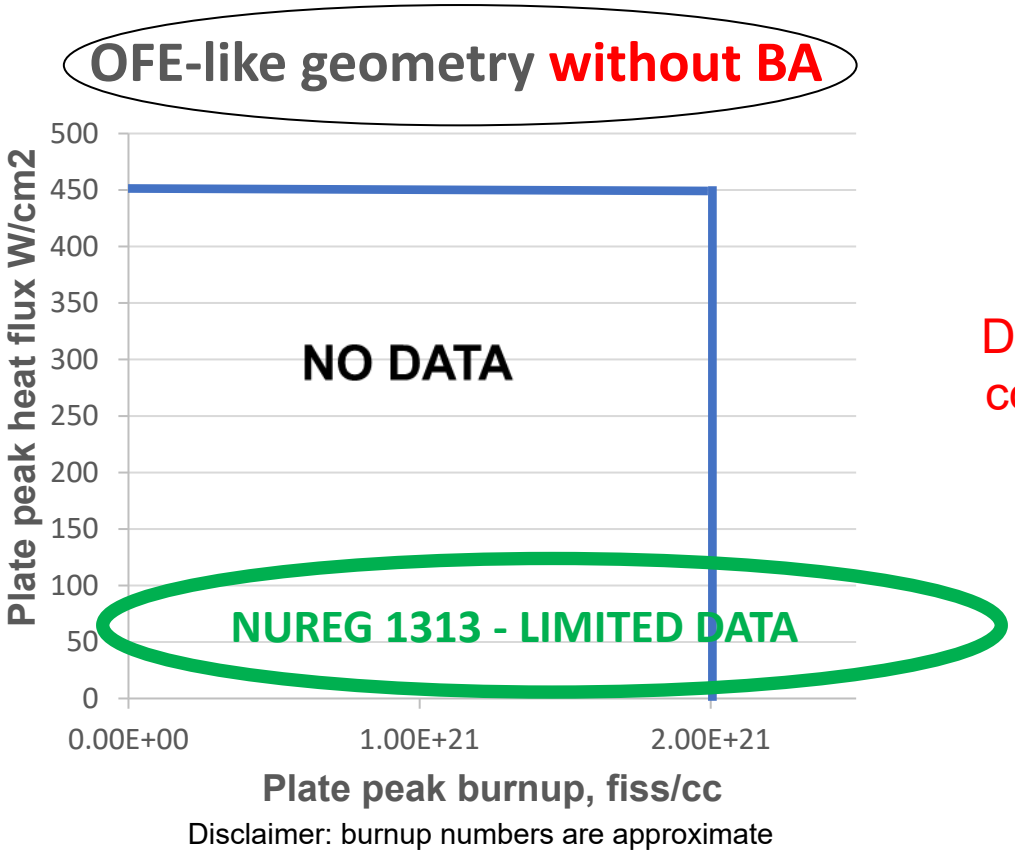
Factors affecting fuel performance



NUREG-1313 – What do we have?

- Silicide fuel at 4.8 g U/cc
- Not written with HFIR in mind:
  - No burnable absorbers
  - No contoured fuel
  - No 30 mils thick fuel, max fuel thickness 20 and 22.5 mils
- 140 W/cm^2 peak heat flux
- 80 at.% burnup

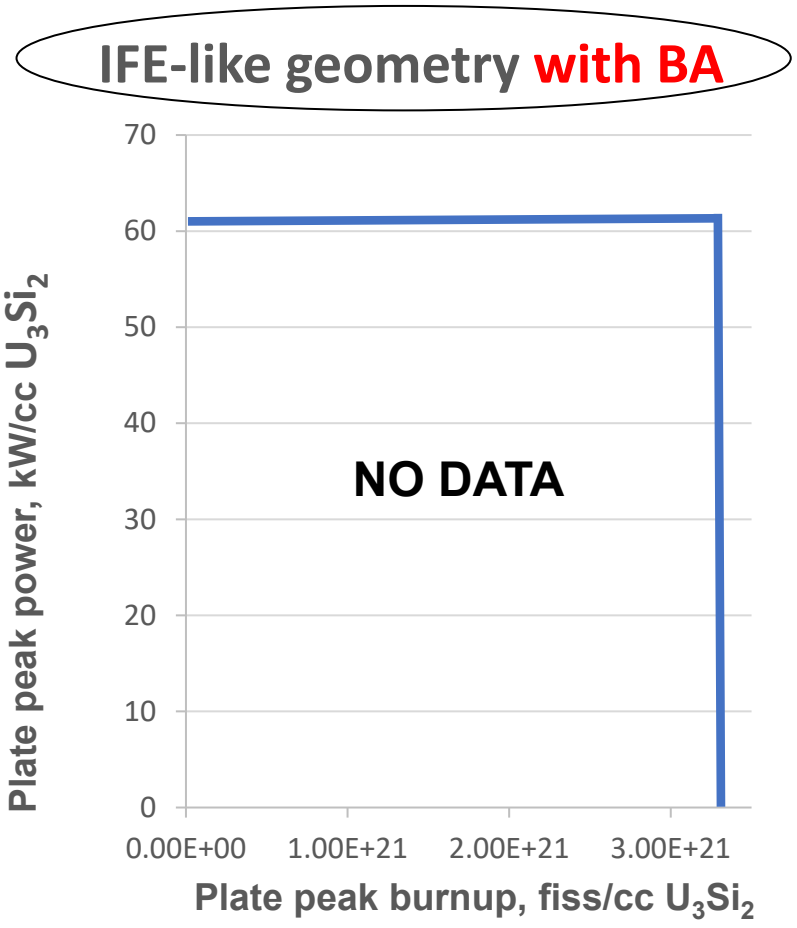
HFIR silicide OFE fuel operating envelope



Disclaimer: burnup numbers are approximate

Data is needed for thicker fuel meat to confirm or rule out power/temperature effects

HFIR silicide IFE fuel operating envelope



Data is needed for IFE-like fuel to confirm or rule out effects of BA and power/temperature on fuel performance

FUTURE-HFIR Silicide Scoping Test

Main question:

Does silicide fuel work at high power in OFE (thick contoured fuel) and IFE (thin contoured fuel with BA) configurations?

Are there distinct effects on fuel performance of:

- High power/temperature
- Burnable Absorber
- HFIR fuel geometry

If there are distinct effects – then new fuel performance correlations have to be developed

If not – NUREG-1313 correlations can be used with some limited confirmation through testing

Please see Warren Jones presentation

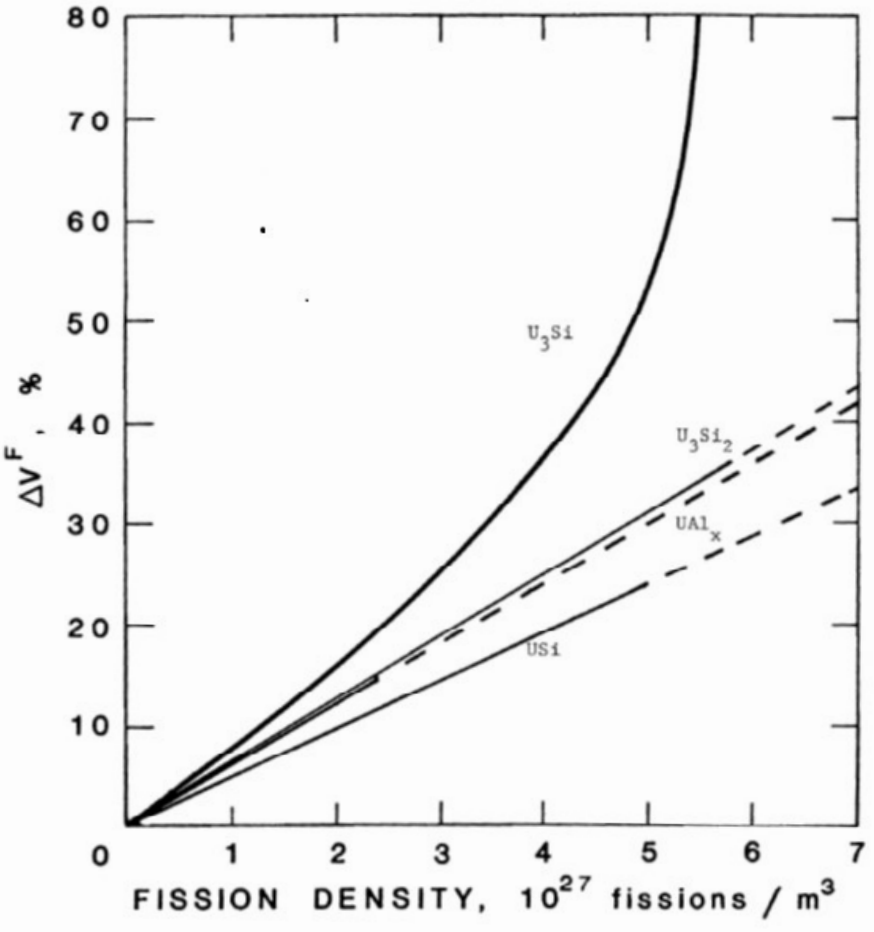
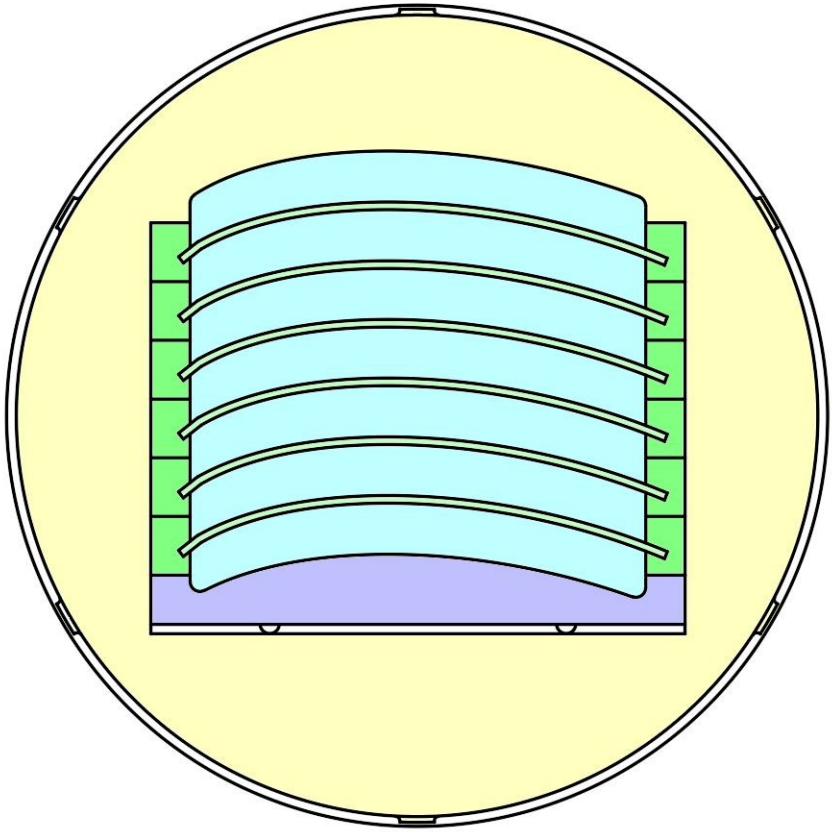


Fig. 9. Swelling of Uranium Silicide and UAl_x Fuel Particles vs. Fission Density in the Particle. Dashed Lines Indicate Fission Densities Not Attainable in LEU Fuel.

FSP-HFIR Fuel Qualification Test (Data Gathering)

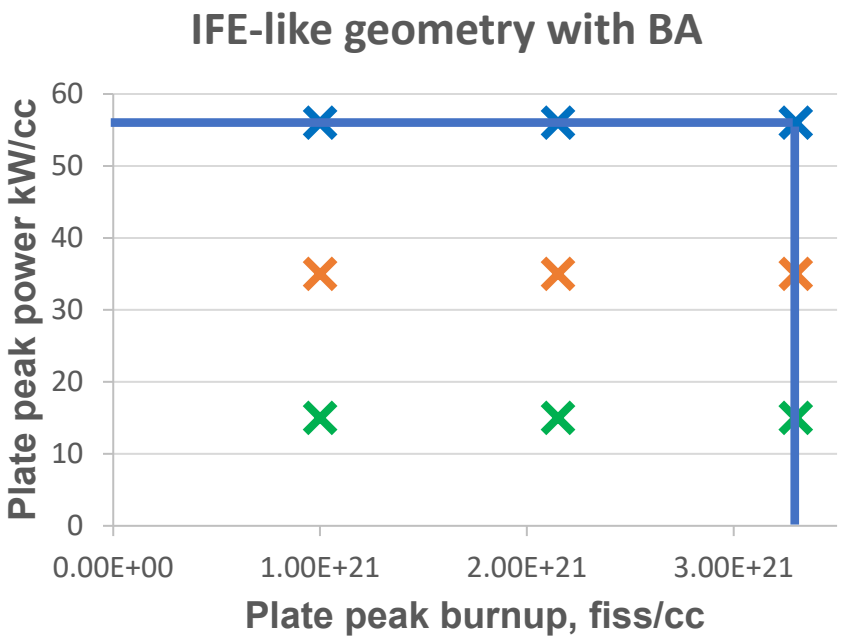
Main goals:

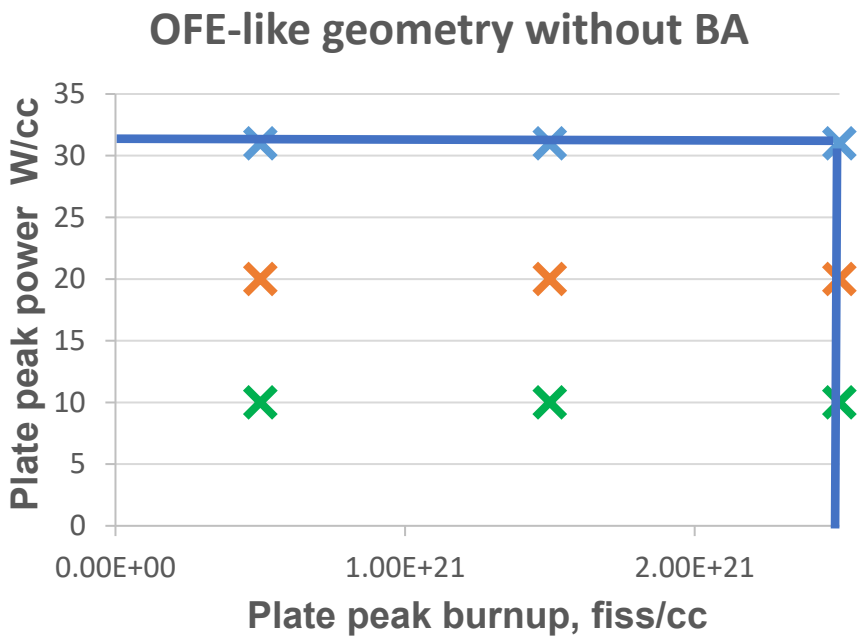
- Demonstrate and confirm acceptable performance of the large scale fuel plates fabricated by qualified process at prototypic conditions, up to bounding
- Generate fuel performance correlations for prototypic plate geometries (IFE with BA and OFE without BA) in prototypic conditions (new curves), up to bounding,
- Collect thermo-physical properties data, those impacted by fuel geometric configurations, BA and high power/temperature,
- Provide statistical confidence in the data required by HFIR
- Detailed data needs will be defined by HFIR



Graphics is courtesy of Greg Housley

FSP-HFIR Fuel Qualification Test (Data Gathering)





DDE-HFIR licensing test (at BR2)

Main goal:

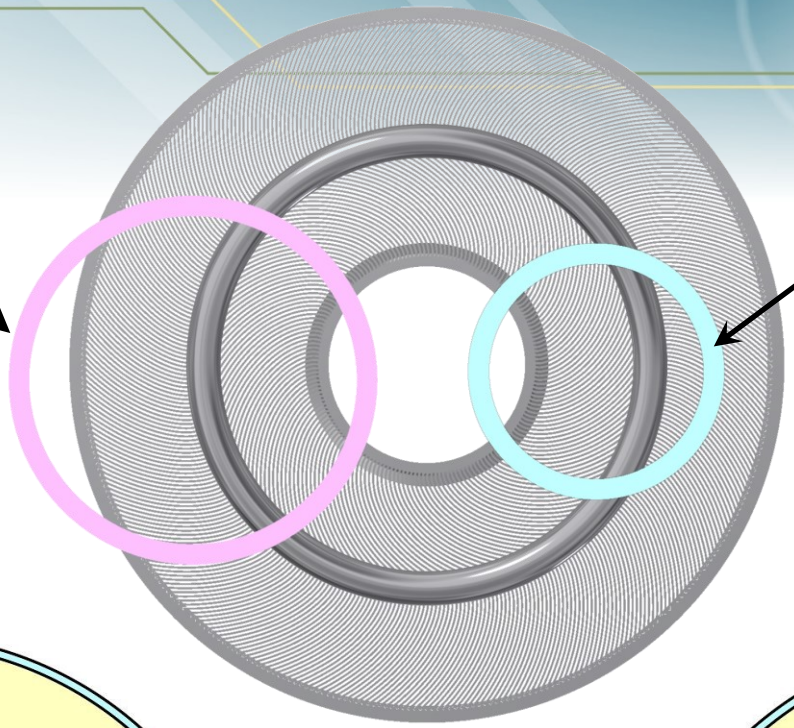
- Demonstrate and confirm acceptable performance of the representative assembly of plates at prototypic conditions
- Provide required statistical confidence

Main problem:

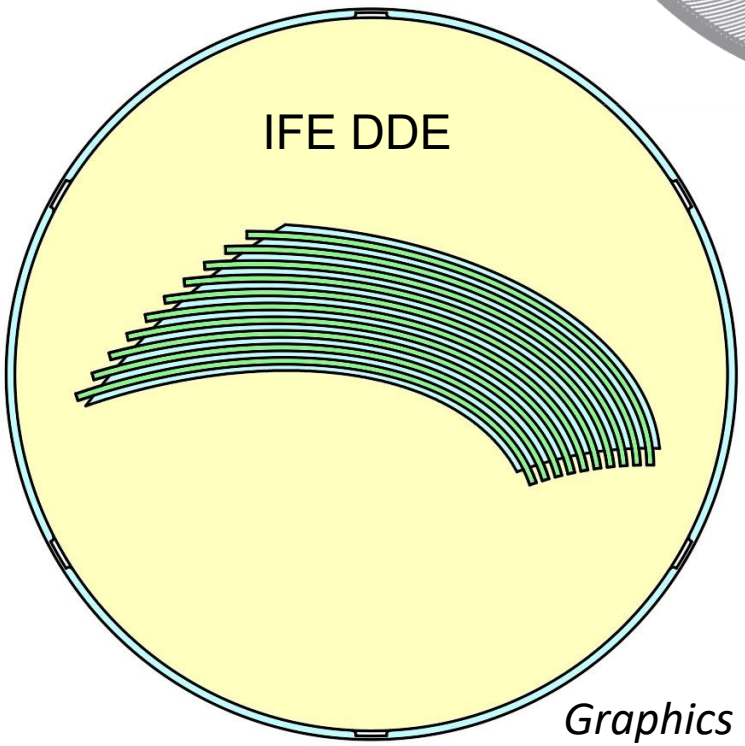
- HFIR element is 2-3 times larger in diameter than the largest available test positions in BR2 and ATR
- DDE-HFIR will not look anything like the actual HFIR
    - Would 10 plates from OFE and 10 plates from IFE with 50 mils channels be adequate to represent HFIR element?
    - No similar test was done in the past

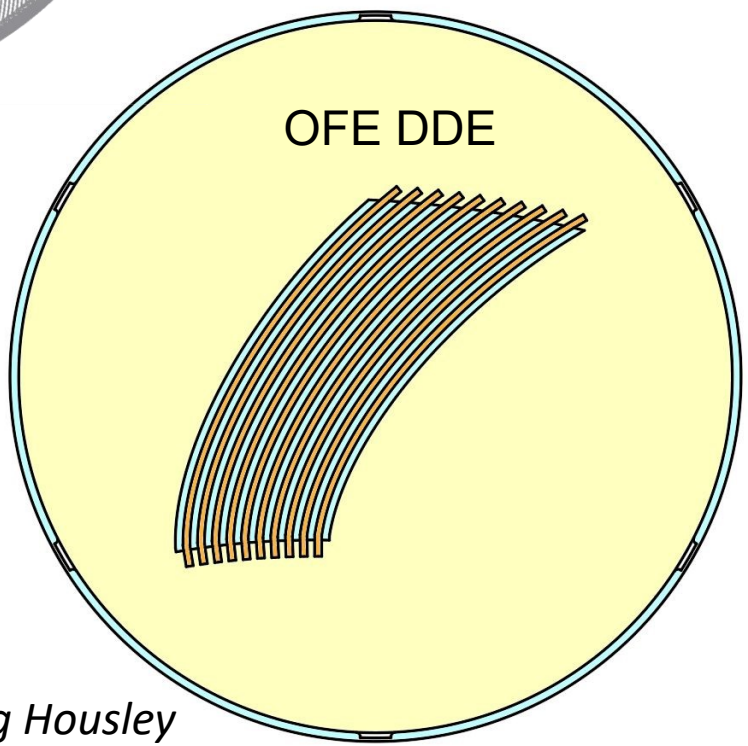
BR2's Channel Ø8.00

ATR's NEFT Ø5.25



HFIR O.D. = Ø1





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