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HFIR Fuel Development Effort

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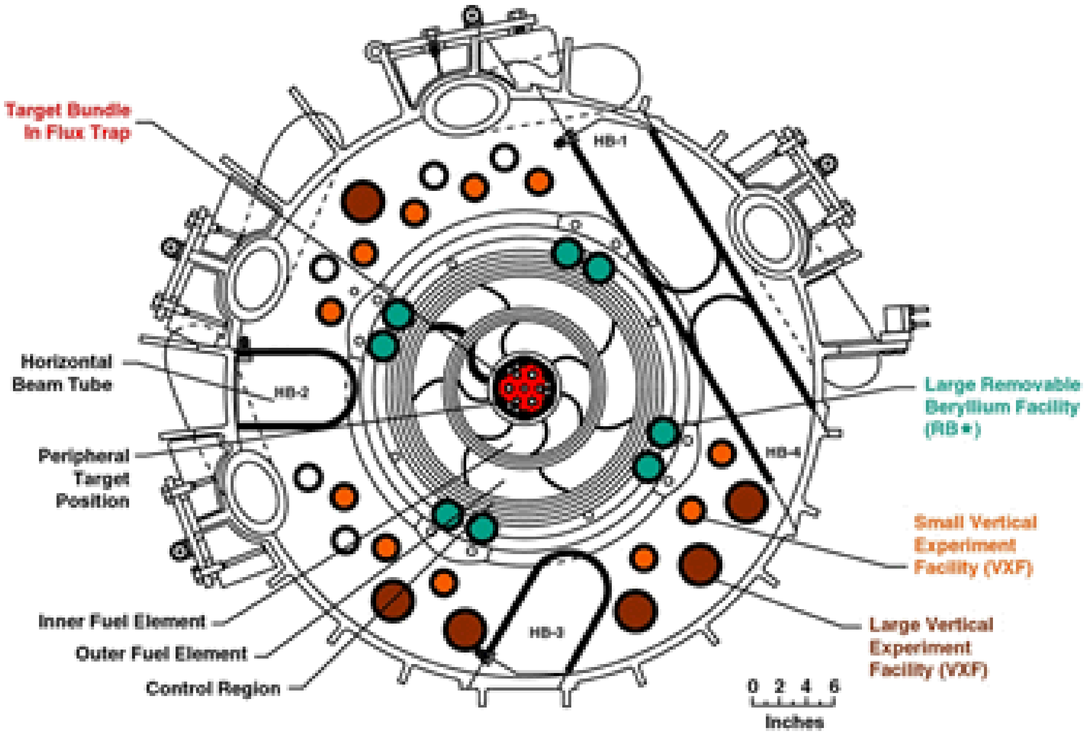
Outline

- The High Flux Isotope Reactor
- From HEU to LEU – Design Process
- Fuel Development & Manufacturing Efforts
- Future Plans

The High Flux Isotope Reactor

- Oak Ridge, TN - First critical in 1965
- Operated at 100MW until 1986 and then at 85MW (vessel embrittlement issue)
- Designed to produce heavy isotopes (e.g. ^{252}Cf)
- Today's primary missions also include: neutron scattering, ^{238}Pu production, material irradiation, …
- Core is made of 2 HEU elements replaced at end of ~25 day cycle: 171 + 369 = 540 involute plates



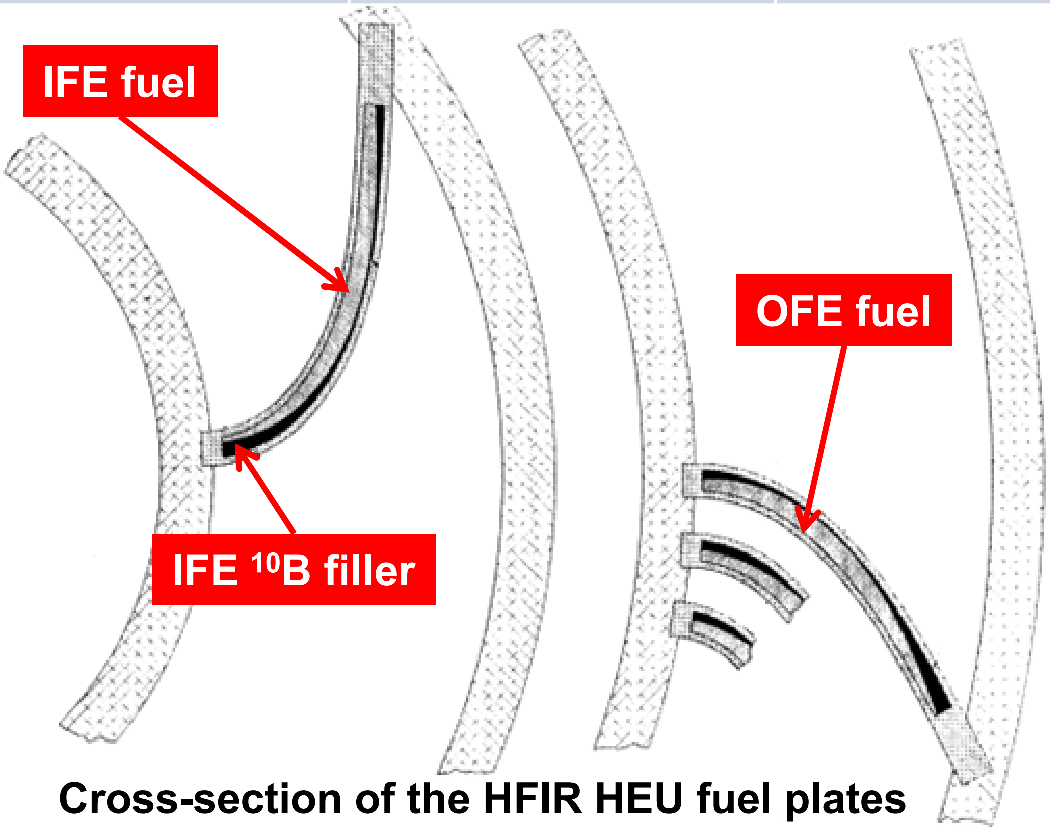
Top view of the HFIR core
(reflector, fuel elements, flux trap)

Top view of the HFIR elements

The High Flux Isotope Reactor

- **HEU fuel plates have unique complex features…**

HFIR HEU COMPLEX FUEL FEATURES	Variable fuel thickness in Inner Fuel Element (IFE)	Variable thickness filler contains burnable absorber (IFE)	Variable fuel thickness in Outer Fuel Element (OFE)
Functional purpose	Reduce edge power peaking	• Reduce edge power peaking • Shift power to outer element • ^{10}B consumed for full core life	Reduce edge power peaking



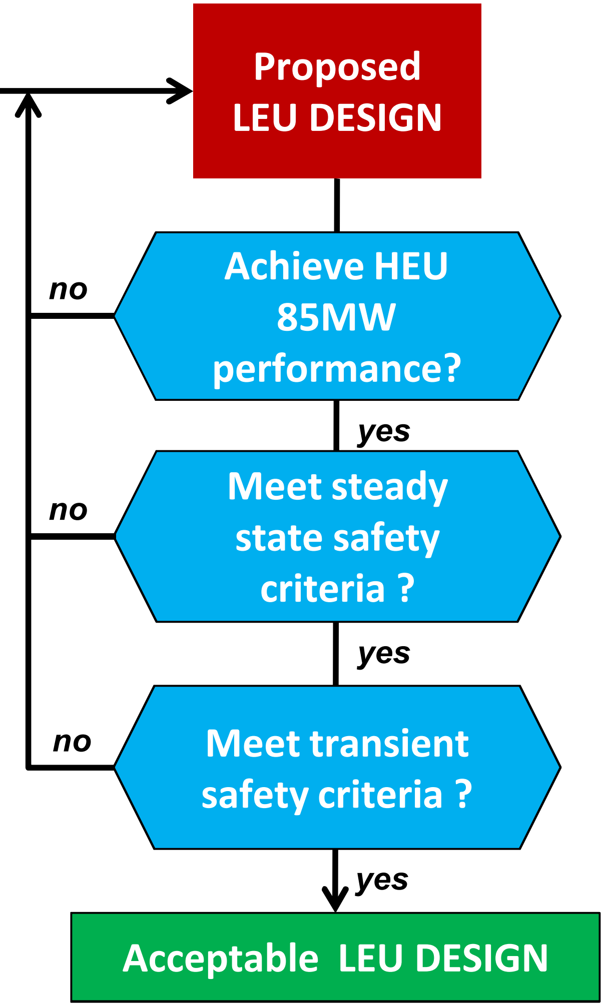
Cross-section of the HFIR HEU fuel plates

Top view of the HFIR elements

From HEU to LEU – Design Process

Design variables include:

- Fuel dimensions (thickness/height)
- Fuel shape (contoured edges at the bottom or on the side)
- Reactor power level
- Amount, nature & location of neutronic absorber



HFIR Conversion Element Designs

- Several conversion element design options have been proposed
- Initial feasibility of fabrication underway for potential HFIR LEU element designs

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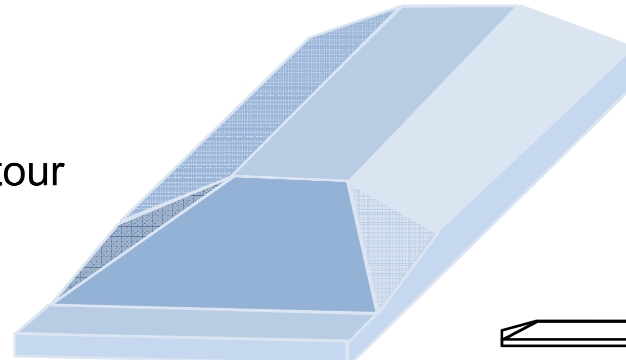
Evolution of the ORNL's HFIR "best LEU design"

2012

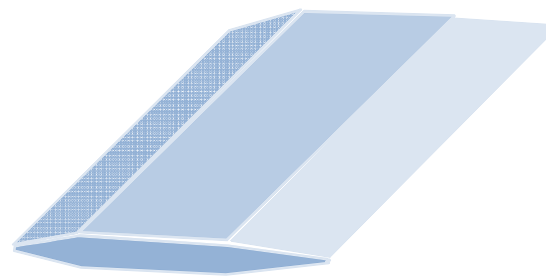
- Lateral fuel gradient
- Last 3cm of the fuel, axial contour
- Burnable absorber in IFE

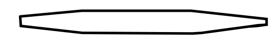


last 3cm, IFE, OFE fuel thickness progressively reduced axially. Last cm, fuel is flat (75μm = 3mil)

2014

- Lateral fuel gradient
- Fuel centered and symmetric
- Hafnium at bottom to replace axial contour
- IFE ^{10}B moved from fuel plate to side plates





2015

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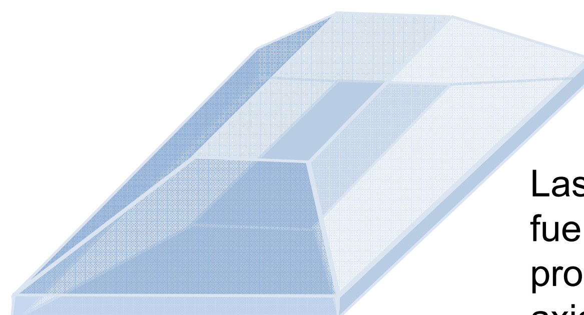
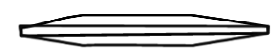




Last 3cm, IFE, OFE fuel thickness progressively reduced axially.

From HEU to LEU – Design Process

- **Ongoing design effort is aimed to find a HFIR LEU design that operates reliably and can be manufactured affordably**

- **ORNL & ANL are working together on the following options:**

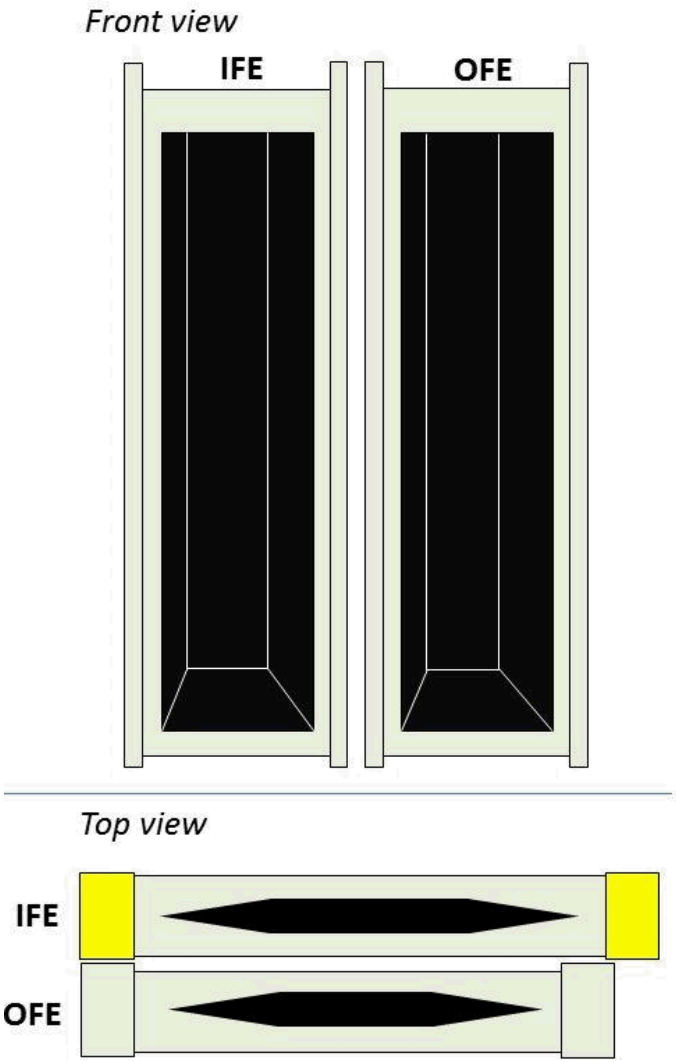
- **Use of wire neutron absorber (as in *BR2, JMTR, HFR Petten*)**
  - ***> backup solution to Al-B side plates but compatibility with element fabrication has to be evaluated***
  - ***> reduce lateral power peaking***
  - ***> reduce design constraint on lateral contouring***

- **Use of annular absorber plate (as in *FRM-II, RHF*)**
  - ***> reduce axial power peaking***
  - ***> reduce design constraint on axial contouring***

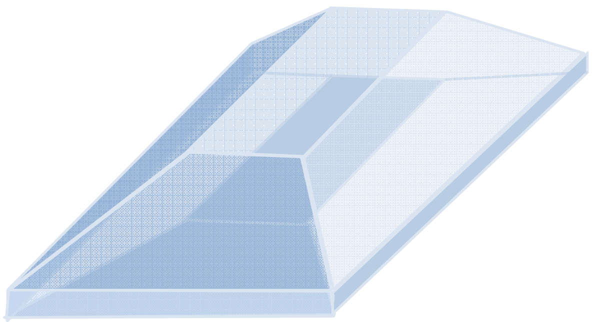
- **Use of modern CFD tools to take credit for heat conduction in safety analysis**
  - ***> reduce axial and lateral power peaking used in safety analysis***
  - ***> reduce constraint on both lateral & axial contouring***
  - ***> similar methods already used in U.S. test reactor safety basis for HEU or other conversion designs (NBSR, MITR, MURR)***

Fuel Development & Manufacturing Efforts

- **FFC & FD baseline activities for HFIR reflect “best design” candidates:**



- **Development of Al-B alloy for side-plates**
- **Development of a fabrication process allowing production of airfoil-like monolithic fuel plates**



Fuel Development & Manufacturing Efforts

- **Development of Al-B alloy for side-plates**

The USHPRR program has started a project to produce/test/qualify Al-B alloy to be used in the HFIR side-plates

Phase	Main scope
1	Production of master alloy
2	Testing in HFIR and PIE
3	Data assimilation/QA, procedures and specifications

Fuel Development & Manufacturing Efforts

Development of a fabrication process allowing production of airfoil-like monolithic fuel plates

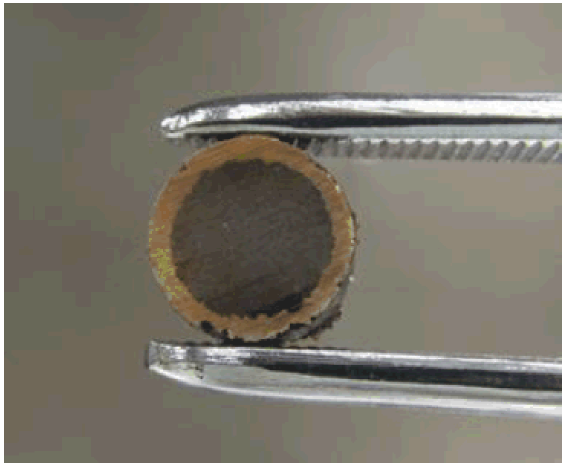
- **Co-extrusion process**

- **Hot rolling of HFIR shaped foils**

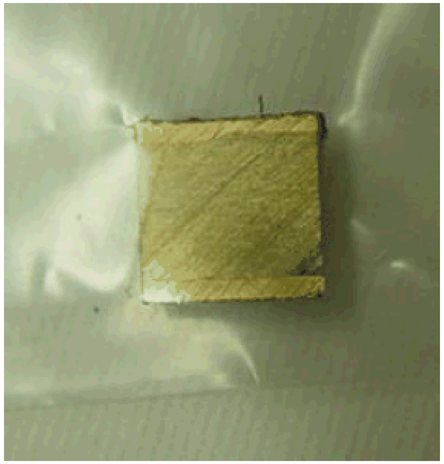
- **Bare roll and then apply Zr**

Fuel Development & Manufacturing Efforts

- **Co-Extrusion process**



(a)



(b)

Macro-Images of the Extruded DU-10Mo Rod: Transverse (a) and Longitudinal (b) [PNNL-23045]

- Dimensional tolerances and shape control still need to be solved

- Test extrusions included bronze sleeve over U-10Mo billet.

Fuel Development & Manufacturing Efforts

- **Hot Rolling**

  - **Symmetrical fuel shape should be easier to manufacture than non-symmetrical shapes**

  - **2-D numerical models for rolling end of fuel element gave promising results**

  - **3-D numerical models for using multiple shaped rollers are being developed**

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Future Plans

- **Simplified Baseline for HFIR complex fuel qualification and Conversion:**

Activity	start	end	Scope / comments
Complex foil rolling	2015	2017	Develop complex foil rolling and technology transfer to vendor
MP-ABA	2014	2019	Test possibility of having absorber in fuel plates.
Fueled Miniplate Expt.	2014	2021	Test at HFIR condition
FSP HFIR	2019	2023	Test HFIR full size plate in ATR
HFIR DDE	2023	2026	Test HFIR full size multi-plate IFE / OFE in BR2
Upon completion of all tasks above: Complex fuel qualification report			
Safety basis	2013	2016	Establish safety basis for HFIR LEU 100MW
100MW LEU	2016	2020	Demonstrate operation at 100MW is possible
Low power LTC	2021	2028	Series of experiments required by safety basis through validation of predicted/measured system responses
100MW LTC test	2022	2031	Lead test core at 100MW
Upon completion of all tasks above: HFIR conversion– End of USHPRR program			