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A Plan to Qualify New Fuel for the High Flux Isotope Reactor for Material Minimization Poster

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Idaho National Laboratory

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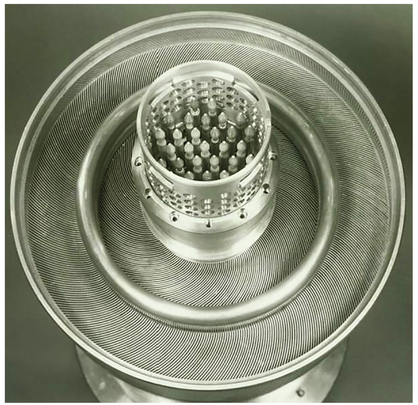
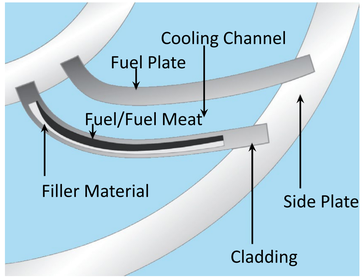
* Idaho National Laboratory, ** Oak Ridge National Laboratory, *** Argonne National Laboratory

High Flux Isotope Reactor (HFIR)

- U.S. Department of Energy (DOE) Office of Science (SC) User Facility that is operated at the Oak Ridge National Laboratory (ORNL)
- Completed in 1965 and operating at 85 megawatts
- Versatile research reactor providing one of the highest steady-state neutron fluxes of any reactor in the world for neutron scattering experiments focused on fundamental and applied research on the structure and dynamics of matter, materials irradiation studies, and production of medical, industrial, and research isotopes
- The reactor
  - Core is cylindrical, approximately 0.61 m (2 ft) high and 38.1 cm (15 in.) in diameter
  - 12.70-cm (5-in.)-diameter hole, the "flux trap," forms the center of the core
  - Target is positioned on the reactor vertical axis within the flux trap
  - The fuel region is composed of two concentric fuel elements: inner element contains 171 fuel plates and outer element contains 369 fuel plates
  - The fuel plates are curved in the shape of an involute, thus providing a constant coolant channel width



Top View of HFIR Inner and Outer Fuel Elements with Central Flux Trap



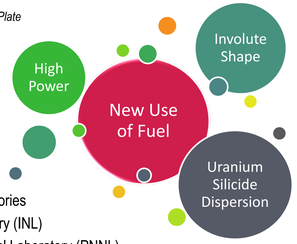
Current HFIR Highly Enriched Uranium Fuel Plate

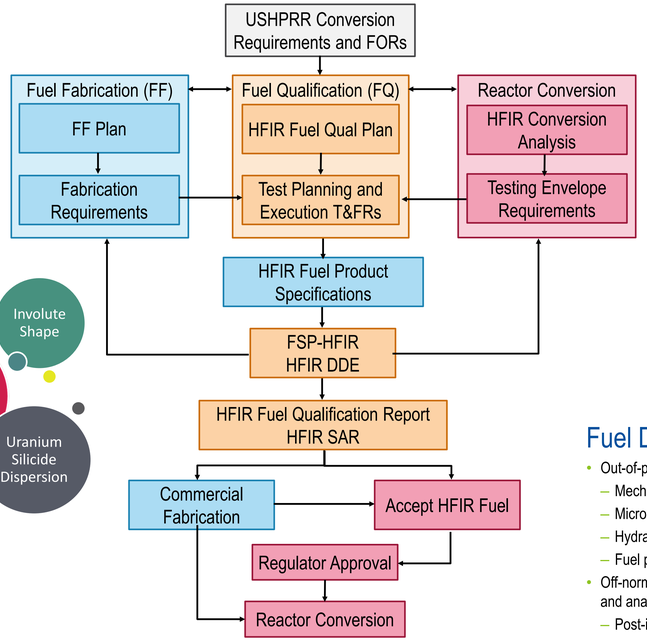
Purpose

- HFIR at ORNL is being evaluated for conversion to LEU using a uranium silicide fuel, U_3Si_2-Al dispersion fuel
- Scope divided into four Pillars managed by Laboratories
  - Fuel Qualification (FQ) - Idaho National Laboratory (INL)
  - Fuel Fabrication (FF) - Pacific Northwest National Laboratory (PNNL)
  - Reactor Conversion (RC) - Argonne National Laboratory (Argonne)
  - Cross-Cutting (CC) - Savannah River National Laboratory (SRNL)

Background

- The primary objective is to achieve permanent threat reduction by minimizing and when possible, eliminating weapon-usable nuclear material around the world
  - Office of Material Management and Minimization Program's within the DOE/ National Nuclear Security Administration
- Therefore, the U.S. High Performance Research Reactor (USHPRR) Project is pursuing a fuel qualification and licensing to convert high-performance research reactors in the United States from using highly enriched uranium (HEU) fuel to using low-enriched uranium (LEU) fuel
- Uranium silicide fuel of 4.8 gU/cm^3 is qualified in NUREG-1313 at an approximate heat flux of 1.4 MW/m^2, which is below HFIR conditions





HFIR Fuel Qualification and Reactor Conversion Process

HFIR Fuel Qualification Steps

- Select Design Features
- Develop Requirements for Fuel Qualification
- Develop Fuel Specification
- Demonstrate Fabrication
- Generate Data and Analysis Documenting Qualification Requirements are Met
- Submit U_3Si_2-Al Fuel Qualification Report

- Scoping
- Evaluate options

- Fuel performance data
- Prototypic geometries and conditions

- Partial element
- Prototypic conditions
- Element stability

- Tested in the HFIR
- Low power then High power after DOE approval

Sequence of HFIR Tests of Increasing Complexity

Requirements for Qualification

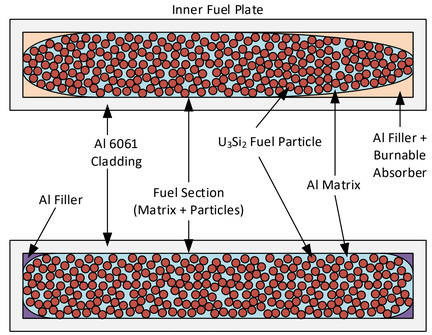
- Maintain mechanical integrity
- Maintain geometric stability
- Stable and predictable behavior
- Establish reactor-mission performance envelope
- Test to verify design requirements

Requirements for Fuel Acceptance

- Fabrication process specifications and acceptance criteria is based fuel characterization and manufacturing evaluations
- Fuel elements shall be fabricated and tested to support the development of the reactor-specific conversion safety analysis
- Acceptance criteria for manufacturing fuel elements shall be based on the U_3Si_2-Al fuel qualification, reactor-specific conversion safety analysis, and manufacturing evaluations
- The HFIR shall provide additional safety-analysis data from demonstration tests to the DOE for DOE's review

Fuel Data Collection

- Out-of-pile testing and analysis
  - Mechanical and thermophysical properties
  - Microstructural characterization
  - Hydraulic flow testing
  - Fuel performance modeling
- Off-normal fuel performance behavior testing and analysis
  - Post-irradiation blister testing
- In-Canal Examinations
  - Channel-gap width measurement
  - Ultrasonic scanning
  - Visual examination
- Post-Irradiation Examination
  - Radiographic inspection
  - Gamma scanning
  - Analytical chemistry
  - Microstructural examination



U_3Si_2-Al Inner and Outer Fuel Plate Schematic Representation

Uranium Silicide Fuel with Burnable Absorbers

- Highest density LEU fuel qualified and licensed for use in U.S. research and test reactors at up to 0.95 g U-235/cm^3 (4.8 g U/cm^3 at an enrichment of 19.75 wt. % U-235)
- Proposed design with and without burnable absorber for the HFIR
- The HFIR exceeds the approved upper bounds for qualified uranium silicide dispersion fuel in NUREG-1313 with a fuel loading of 4.8 gU/cm^3 at a maximum heat flux of 1.4 MW/m^2 and maximum fuel-section temperature of about 130°C

Conclusions

- First time silicide fuel will be used in USHPRR
  - At a high power with estimated peak heat flux above 4 MW/m^2
  - In a complex fuel design
- Data from the HFIR Silicide Fuel Qualification campaign will
  - Be used to prepare the reactor conversion SAR analyses and subsequent Safety Basis Supplement
  - Ensure that the LEU fuel will meet the key performance metrics and requirements for safe operation in HFIR

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