

35th Regulatory Information Conference: New Fuels Licensing Readiness

William McCaughey

Director of Advanced Fuels Technologies

Office of Nuclear Energy

U.S. Department of Energy

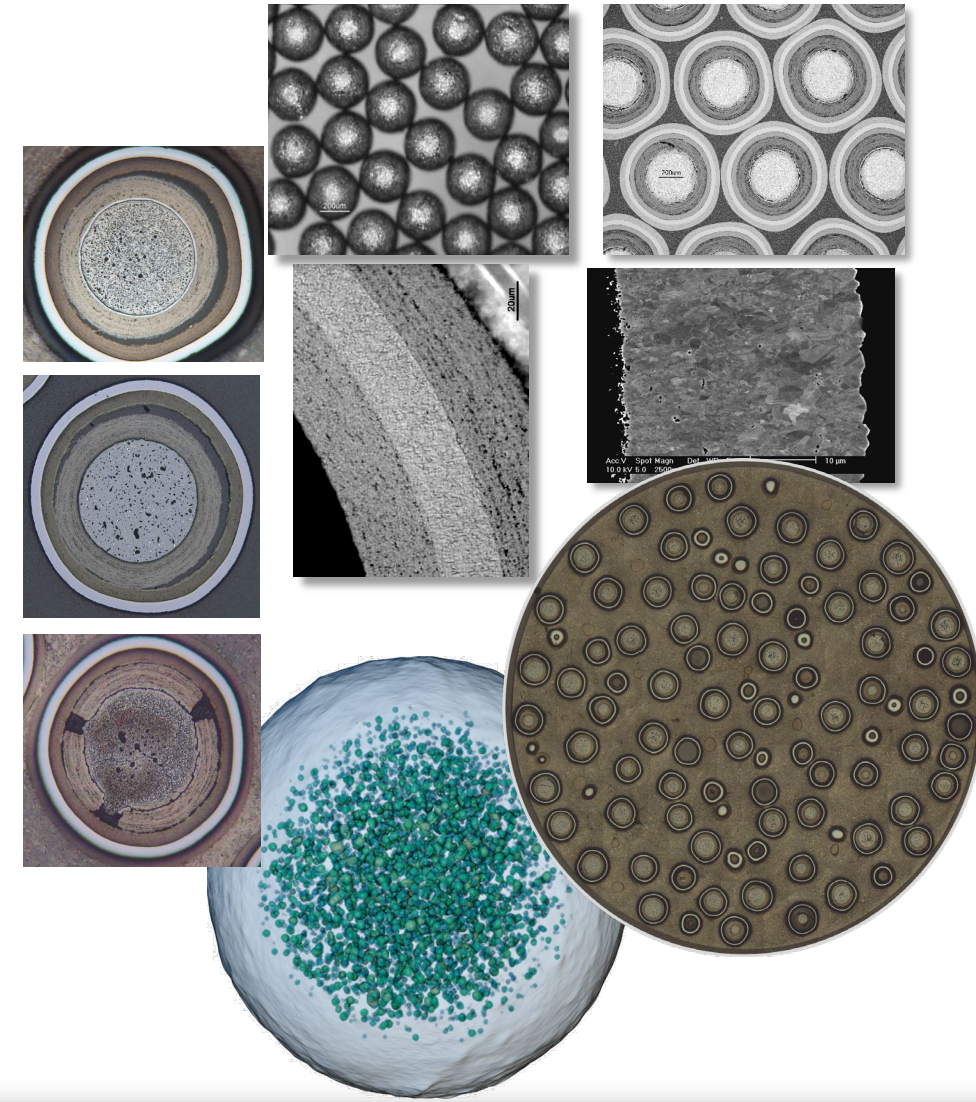
March 14, 2023

Agenda

- **Advanced Reactor Fuels**
- **High-Assay, Low-Enriched Uranium**
- **Accident Tolerant Fuels**
- **Summary**

TRISO Fuel – Many Designs Leveraging Deep Investments

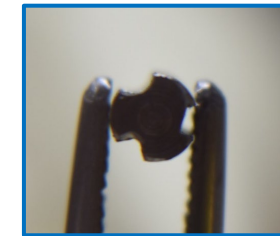
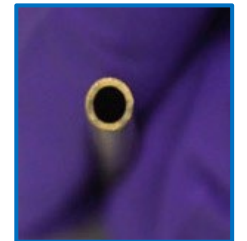
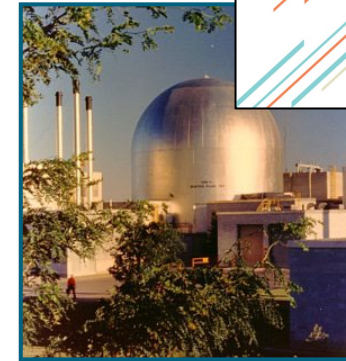
- DOE has invested over \$400M in the TRISO and graphite qualification programs.
 - Advanced gas reactor (AGR) fuel qualification program has performed fabrication, irradiation, post-irradiation examination (PIE), and safety testing on TRISO particle fuel since 2002.
 - Tested to 1800°C – exhibits low levels of particle failure and maintains excellent fission product retention.
 - Average fuel burnup that is approximately 4 times higher than existing reactors and significantly improves overall economics.
 - Excellent long-term robustness which provides excellent spent fuel containment after use.
 - Collaborated with Electric Power Research Institute (EPRI) on a Topical Report which has been endorsed by the NRC (ML20336A052) and is reducing regulatory risks for high temperature designs planning to use this fuel type.
- **TRISO fuel has been selected for several high temperature reactor designs.**
- **DOE is continuing PIE on irradiated fuel to quantify fission product retention characteristics and fuel performance in response to varying reactor fluence and temperature, support source term determinations, and provide experimental data required to support future commercial fuel fabrication activities.**



Metallic Fuel

LIFT – *Leading Innovation in Fuel Technology*

- **Goal: Perform R&D to support qualification of metallic fuel technology to enable advanced reactor deployment and development**
 - Use TRISO fuel qualification as inspiration
 - Reduce risk for market entry
- **Objectives:**
 1. Establish reference fuel performance basis for U-10Zr/HT9 using legacy R&D and modern tools to fill gaps
 2. Innovate metallic fuel design using accelerated techniques to maximize fuel applications and performance potential
 - **5 years** – Develop & demonstrate accelerated fuel qualification to deliver Na-free metallic fuel option

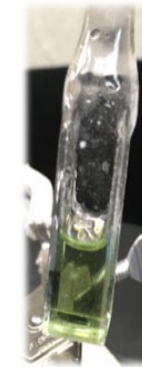


Molten Salt Fuels Development

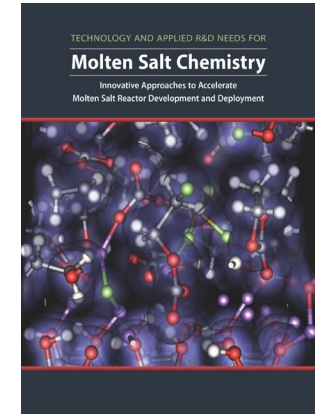
- Legacy of solid fuel development data, models, platforms, and tools has limited utility for developing molten salt fuels.
- Establishing cross-cutting, multidisciplinary teams at national labs and universities to support molten salt fuel R&D:
 - Developing salt preparation, recycling and purification methods
 - Characterizing and understanding salt structure and property relationship
 - Developing in-situ measurements for salt systems
 - Filling salt data gaps and developing atomic level models to predict salt properties and behaviors
 - Utilizing computer simulations and machine-learning approaches to accelerate the salt fuel developments



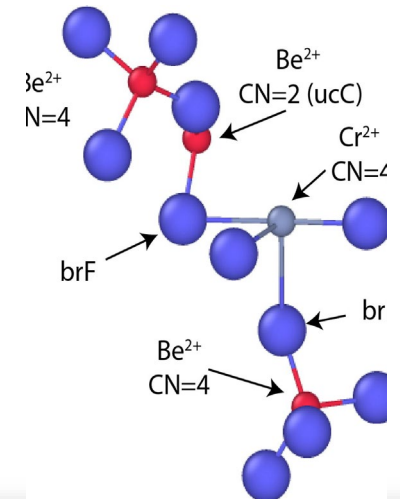
UCl_3 -
 RbCl
melt at
 850°C



UCl_4 -
 CsCl
melt at
 750°C



<https://www.ornl.gov/content/molten-salt-chemistry-workshop>



HALEU

HIGH-ASSAY LOW-ENRICHED URANIUM



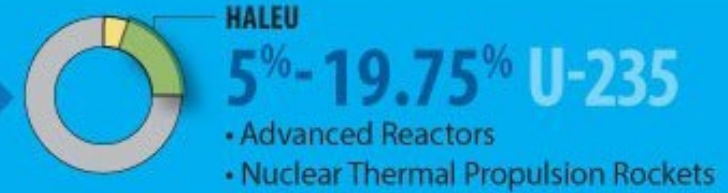
- Only commercial scale supplier is TENEX in Russia
- \$100M FY 2023 Enacted
- \$700M Inflation Reduction Act

WHAT IS IT?

Uranium enriched between

5% AND 20%

in uranium-235—the main fissile isotope that produces energy during a chain reaction.



ALLOWS FOR...



Smaller Designs



Longer Life Cores



Increased Fuel Efficiency



Less Waste

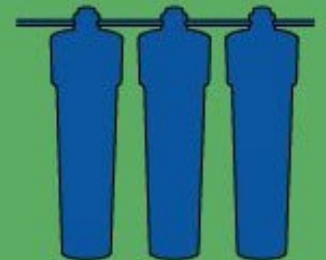
HOW IT'S MADE

Chemical Processing

Recycle used government-owned HEU and downblend to HALEU.

Enrichment

Gas centrifuges separate uranium isotopes by weight to produce a higher percentage of U-235 in the uranium.



HALEU: Energy Act and Inflation Reduction Act

Energy Act of 2020, Section 2001

- A. Criticality benchmark data
- B. Design and license transportation packages
- C. NRC certification
- D. Consider options for DOE acquisition
- E. Biennial survey
- F. Establish consortium
- G. Cost recovery
- H. Establish capability to acquire/provide HALEU

Inflation Reduction Act

- \$100 million for A-C
- \$500 million for D-H
- \$100 million for support activities
- Remains available through September 30, 2026.
- To the maximum extent practicable, use a competitive, merit-based review process.

Accident Tolerant Fuels

- **Near-Term Concepts**

- Coated Cladding
- Doped UO₂

- **Long-Term Concepts**

- Iron-Chrome-Aluminum Cladding
- Silicon Carbide Cladding
- High Uranium Density Fuel

- **Uranium Enrichment**

	High-Assay, Low-Enriched Uranium	
Current LWR Fuel	ATF Fuel at High Burnup	Advanced Reactor Fuel
0% < E ≤ 5%	5% < E ≤ 10%	10% < E < 20%

Test Facilities

- Advanced Test Reactor (INL)
- High Flux Isotope Reactor (ORNL)
- Massachusetts Institute of Technology Reactor
- Transient Reactor Test Facility (INL)
- Severe Accident Test Station (ORNL)

INL – Idaho National Laboratory

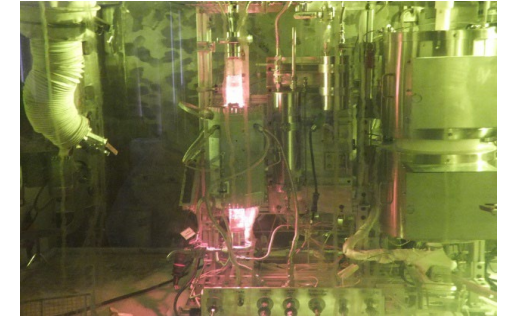
ORNL – Oak Ridge National Laboratory

Shipping and Post-Irradiation Examination

- **Irradiated test rods are shipped from commercial reactors to the national laboratories.**
 - The first two shipments were made in 2020 and 2021.
 - Three shipments are planned for 2023 and 2024.
- **Post-irradiation examination (PIE) is performed at Idaho National Laboratory, Oak Ridge National Laboratory and Pacific Northwest National Laboratory.**
- **DOE is preparing a national shipping and PIE plan in order to make future shipping campaigns routine and coordinate PIE among the national labs.**

Loss of Coolant Accident Test Plan

- **Loss of Coolant Accident (LOCA) test plan developed to address broad stakeholder needs**
 - Leverages the best PIE capabilities in the country
 - Address cross-cutting stakeholder needs
 - Test matrix tailored to large break LOCA conditions
 - Experimental evaluation of identified R&D gaps in fuel fabrication, relocation and dispersal
 - First of a kind approach using both in-pile and hot cell testing facilities
 - Novel in-situ instrumentation



Severe Accident Test Station

2023 | 2024 | 2025 | 2026 | 2027

9 experiments

TREAT LOCA Device Design,
Fabrication, and Testing

TREAT-LOC-C Fresh Fuel,
In-Pile LOCA Commissioning

3 years, ~9 experiments/each facility

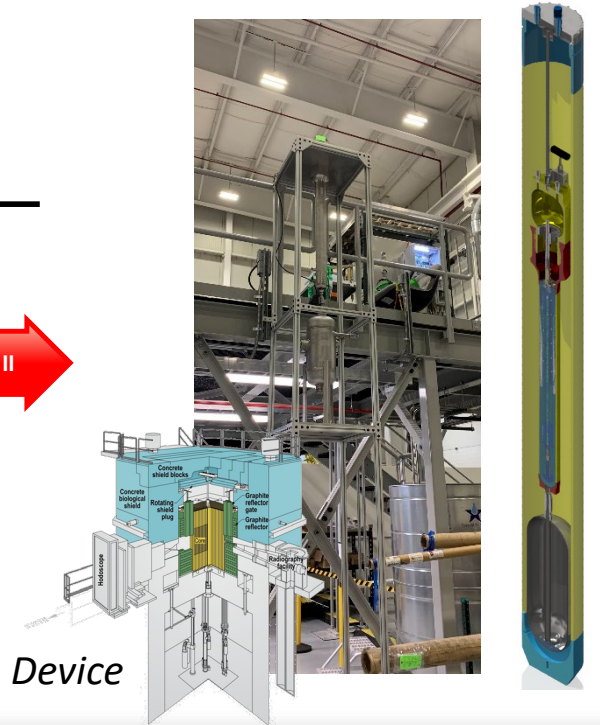
TREAT-LOC-HBu and SATS-HBu

- Tieback testing to Halden/SCIP
- DEH and SEH heating conditions

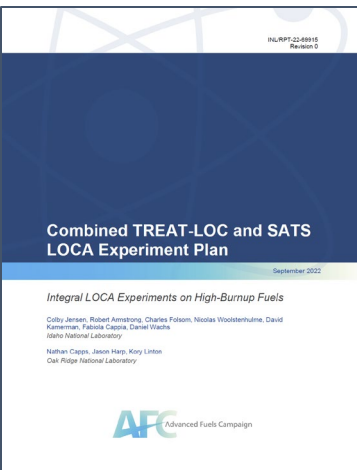
- Burnups from 65-85 GWd/t
- Rod length and rod free volume effects

Phase II

Reirradiation of commercial HBU fuel segments in ATR



TREAT TWIST LOCA Device



Summary

- Among the Office of Nuclear Energy's highest priorities are to support the existing fleet of commercial reactors and to support the deployment of advanced reactors.
- NE provides financial assistance and technical support to industry to develop advanced fuels for the existing fleet and future advanced reactors.
- Most advanced reactors need high-assay, low-enriched uranium and NE is working to establish a diverse, US-based, commercial HALEU market.

The background is a collage of various nuclear energy-related images, including a nuclear reactor cooling tower, a close-up of a fuel assembly, a worker in a hard hat, and a large industrial component, all overlaid with a blue geometric pattern of intersecting lines.

U.S. DEPARTMENT OF
ENERGY

Office of
NUCLEAR ENERGY