DEVELOPMENT OF LIGHTBRIDGE'S ADVANCED METALLIC FUEL FOR WATER-COOLED REACTORS

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Summary

Lightbridge Fuel™ is an advanced metallic nuclear fuel designed for water-cooled reactors, including existing and new builds, as well as small modular reactors (SMRs). The fuel consists of a uranium-zirconium (U-Zr) alloy core, zirconium-alloy cladding, and a central zirconium displacer, co-extruded into monolithic, multi-lobed, and helically twisted rods. This design enhances safety, economics, operational flexibility, and proliferation resistance.

Key advantages include:

- **Low Operating Temperature**: High thermal conductivity and a central displacer that doesn't generate fission heat.
- **Enhanced Coolability**: Improved heat transfer due to metallurgical bonds and increased surface area.
- **Robust Mechanical Design**: Monolithic structure reduces the impact of cladding degradation.
- **Fuel Composition**: Uses High Assay Low Enriched Uranium (HALEU) for higher burnups and reduced waste.

Development activities include:

- **Fabrication and Testing**: Conducted at Idaho National Laboratory and other institutions.
- **Neutronics and Thermal-Hydraulics Studies**: Confirmed the fuel's performance and potential for power uprates and extended cycles.
- **Safety Analyses**: Demonstrated lower temperatures and quicker cool-down times compared to conventional fuels.

- **Irradiation Tests**: Showed good performance and minimal damage under adverse conditions.

Ongoing projects involve collaborations with MIT, Texas A&M University, and the Romanian Institute for Nuclear Research to further evaluate and develop Lightbridge Fuel for various reactor types.

What studies have been conducted on Lightbridge Fuel?

Several studies have been conducted on Lightbridge Fuel to confirm its performance and potential benefits:

1. **Neutronics Studies**:
   - Detailed calculations using MCNP-6 and DRAGON to model the fuel's geometry and performance.
   - Evaluations in various reactor configurations (e.g., Westinghouse AP-1000, AREVA EPR, Seabrook PWR) to assess reactivity control, power uprates, and fuel cycle costs.
2. **Thermal-Hydraulics Studies**:
   - Analytical studies to determine heat flux, coolant flow rates, and heat transfer coefficients.
   - Subchannel calculations using the SC-1 code to develop correlations for Departure from Nucleate Boiling Ratios.
   - Experimental tests on dummy fuel rods to verify hydraulic resistance, critical power, and vibration characteristics.
3. **Safety Analyses**:
   - Simulations using codes like KANAL, RELAP5, RECOL, and TIGR-1 to analyze various operational occurrences and design basis accidents.
   - Comparisons of peak cladding temperatures and cool-down times between Lightbridge Fuel and standard UO2 fuel.
4. **Fuel Performance Studies**:
   - Development of performance models using ANSYS to evaluate temperatures, strains, and swelling.

- Access to a database of performance data from similar uranium-zirconium alloy fuels used in icebreaker ships.

5. **Irradiation Tests**:
   - Proof-of-concept irradiation tests in the IR-8 research reactor to assess fabrication-related faults and performance under irradiation.
6. **Fabrication Development**:
   - Co-extrusion of fuel rods using surrogate materials and investigation of ingot casting techniques.
   - Ongoing fabrication development at Idaho National Laboratory.

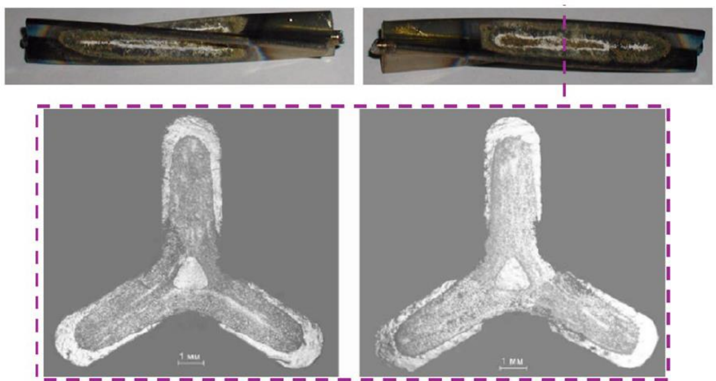
These studies have confirmed the expected performance of Lightbridge Fuel and provided a basis for continued development and potential regulatory licensing.

Summarize irradiation results

The irradiation results for Lightbridge Fuel include:

1. **Proof-of-Concept Irradiation Test**:
   - Conducted in the IR-8 research reactor at the Kurchatov Institute.
   - Involved three Lightbridge 3-lobed metallic and helically twisted fuel rodlets and three icebreaker-type rodlets.
   - Two of the three capsules operated as planned for over 200 days, showing good performance of the Lightbridge rodlets.
2. **Flow Blockage Incident**:
   - The third test capsule experienced flow blockage, leading to dryout conditions for approximately 24 hours.
   - Both the Lightbridge and icebreaker-type rodlets maintained their coolable geometry despite some loss of cladding and fuel material.
   - Minimal damage was observed in the valleys between the lobes of the Lightbridge rodlet.

These results demonstrated the robustness of Lightbridge Fuel under irradiation, even under adverse conditions.



Cross section of a 3-lobed Lightbridge rodlet after ~24 hours under dryout conditions during irradiation showing minimal damage in the valleys between the lobes.