Fast Reactor Working Group

- Multiple developers working on multiple technologies

ARC | Westinghouse | Southern
GE  | Columbia Basin | Exelon
TerraPower | Elysium Industries | Duke
Oklo | General Atomics | EPRI
FRWG Fuels

**Today’s focus**
- Metal • 5 Developers
- Oxide • 2 Developers
- Nitride • 2 Developers
- Carbide • 1 Developer
- Chloride Salt • 2 Developers

**Tomorrow’s opportunities**
- Advanced metal fuels
- Cermets
- Cercers
- Metmets
- Vapor fuels

Today’s focus

Tomorrow’s opportunities
Fast Reactor Fuel Legacy

- Rich history of fast reactor fuel development in the U.S.
- Focused on metal and oxide fuel for SFRs
  > Other fuels also irradiated
- All US SFR developers are pursuing metal fuel designs
Metal Fuel Experience

- Metal fuel is a mature technology
- Phenomena of interest are well characterized
- Over 130,000 pins irradiated in EBR-II and over 1000 pins irradiated in FFTF
- In-core tests
  - 1986 SHRT tests
    - Also involved 40 startup cycles, 8 overpowers, 45 loss of flow tests
    - No fuel failures!
  - RBCB tests
- TREAT tests
- Out of pile tests
- Resilient to variations in manufacturing techniques and tolerant of impurities
Fuel Safety Perspectives

- Instrument and Control
  - Sensors and controls
  - Surveillance and diagnostics
  - HMI

- Materials Analysis
  - Irradiation and property testing
  - Codes and standards development

- Fuel Qualification
  - Demonstrate fuel performance

- Radiological release limits for licensing
- Dose calcs
- Mechanistic source terms

- Structural Analysis
  - Technical bases for analytical tools

- Analytical Codes & Methods
  - Develop required methods
  - Validate codes and models

- Core Design & Heat Removal
  - Codes for physics and thermal hydraulics
  - Heat removal system testing

- Reactor containment
  - Coolant boundary
  - Fission products
  - Fuel elements

- Probabilistic risk assessment

- Accident Sequences & Initiators
Fuel Design Considerations

- Robust fuel behavior can enhance the safety case
  - Fuel changing phase is not necessarily fuel failure, it can be a safety benefit
  - Coolant system can play an important role as a barrier to radionuclide release

- Operational considerations
  - Leakers may not impede operations
Fuel Design Variations

- Extend operating envelope of metal fuels — e.g. advanced metal fuels
- Next generation cladding materials
- Alternative fuel materials
  - Carbides, nitrides, UZrH, cermets, etc.
- Vented fuel and “cladding-free” designs
- General fuel design evolution
General Transient Considerations

- Loss of flow
- Loss of heat sink
- Overpower (reactivity insertion – e.g. rod withdrawal)

- Peak fuel temperature
  - Change of phase
- Peak cladding temperature
- Peak cladding strain
  - Total strain
  - Thermal creep
- Peak structural temperatures and strain
- Radionuclide evolution and release
Separate Effects Results

Sodium
- Pin furnace tests
- Pin segment tests for FCCI
- Differential calorimetry scanning
- High temperature creep tests

Gas
- High temperature creep tests
- Pin and segment furnace tests

Lead
- High temperature creep tests
- Chemical interactions with cladding and fuel
- Corrosion testing

Salt
- Corrosion tests
- High temperature creep tests
- Surrogate chemistry tests
Separate Effects Considerations

- Furnace tests
  - Pin tests
  - High temperature cladding and structural material creep tests
- Fuel-cladding-coolant-structure compatibility and durability
Integral Effects Results

**Sodium**
- Loss of flow
- Reactivity insertions

**Lead**
- Rapid reactivity insertion
- Loss of flow
- Run beyond cladding breach
- Gradual power ramps

**Gas**
- Rapid reactivity insertion
- Loss of flow
- Run beyond cladding breach
- Gradual power ramps

**Salt**
- Rapid reactivity insertion
- Gradual power ramps
- Fuel dump rate effects
Integral Effects Considerations

- Reactivity insertions
- Loss of flow
- Run beyond cladding breach
- Fuel movement effects
Testing Capabilities

- Immersion configurations
  - Static capsule
  - Flowing loop
- Geometry flexibility
  - Single pin
  - Multi pin
- Spectrum flexibility
- Chemistry and corrosion control
- Enhanced hodoscope capabilities
Fuel Sourcing

- High assay LEU supply
  - Associated infrastructure development
- Fuel manufacturing/production
  - Prototyping to commercial scale up
- Plutonium and actinide-bearing UNF materials
Fast Test Reactor

- Accelerate new fuels and materials development
- Enable exploratory studies on fuel design improvements and next generation technologies
- Need for urgency in order to maximize benefit
- Opportunity to support fuel supply chain
Modeling and Simulation

- Existing tools — e.g. BISON, LIFE-METAL, SAS4A/SASSYS
- Legacy data
- Lab development supports verification and validation
  - Industry owns design-specific validation for regulatory purposes
- Mechanistic-driven, meso-scale tools will help inform testing programs
Historical Reports and Data

- **Metal fuels reports and data**
  > Supporting documentation of applicable metallic fuel transient tests, including as-built data packages, as-run conditions, PIE results, and supporting documentation

- **Legacy and modern fast reactor fuel experimental reports and data**
  > Experimental data on UO2, UN, UC, and advanced metal fuel irradiation performance
  > Experimental data on cladding materials

- **Pyroprocessing reports and data**

- **Centralized Reliability Data Organization (CREDO) database of component reliability for liquid metal reactors**
A Comment on Applied Technology

- Applied technology helps protect U.S. intellectual property and information
- Need to improve how U.S. companies access AT
Takeaways

Metal fuel is a mature technology
  > Building on legacy data

Developing new fuels
  > Extending operating envelopes
  > Exploring new concepts

Will require a full suite of supporting capabilities
Closing Thoughts

New fuel development is not trivial, but is manageable and worthwhile.

Excellent timing for fast reactor development, and by extension for TREAT and a new fast test reactor.
Questions