FRWG

Fast Reactor Working Group

Fuel Safety Research Workshop

May 3, 2017

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

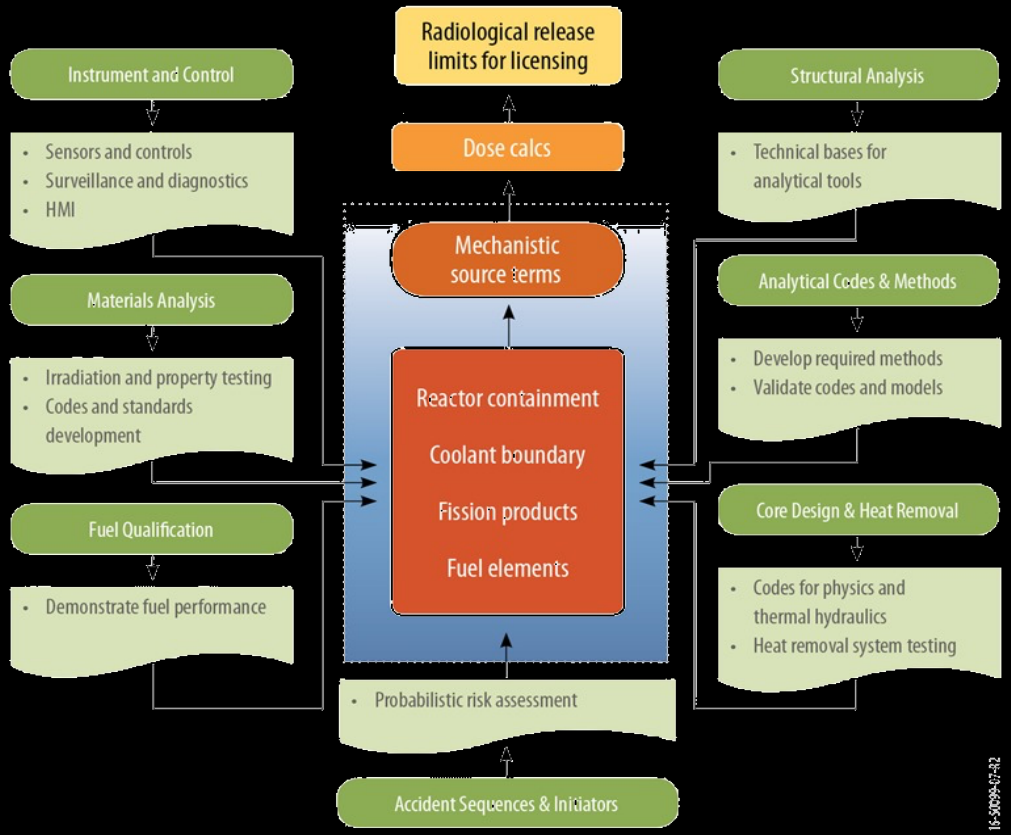
Fast Reactor Fuel Legacy

- 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 130000 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



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

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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

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Sodium
- Loss of flow
- Reactivity insertions

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

Lead
- 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

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