Industry Panel: Advanced Reactor Fuel Challenges

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Our vision is to be the
first to innovate the next
technology, practice or solution that helps us help customers generate safer, cleaner, more reliable energy for more people and a better planet.

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OUR VALUES: *A RECIPE for Success*

- **RESPECT.** We care about each other and value what everyone brings to the table. We believe in strong leadership that builds respect through employee engagement and communication.
- **EXCELLENCE.** Our operations put safety first – nuclear, industrial and occupational – with the highest expectations for outstanding performance, quality and delivery always.
- **CREATIVITY.** Innovation is in our DNA. We value collaborative thinking that turns ideas into solutions that improve life and tackle challenges – even before a problem may exist.
- **INTEGRITY.** We do what we say – with honesty and fairness – even when no one is looking, and we're accountable for the results.
- **PASSION** for customers. We are driven by our customers' success, so it's important to be where they are so we can better anticipate their needs and exceed their expectations.
- **EXECUTION.** We plan our work and work the plan, with flexibility, agility, a solid strategy and superior technology (*FAST*). We anticipate and respond to an ever-changing, global marketplace with a relentless pursuit of safety, continuous improvement, learning and efficiency.

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Advanced Reactor Operating Conditions

- Non-water coolant
  - Lead: potential for high temperature, but corrosion challenges for metals
  - Sodium: small margin for temperature increase due to sodium voiding
  - Gas: no corrosion issues, but metals face strength and creep issues at elevated temperatures
  - Molten salts: radioactive liquid fuel challenges safe operation and maintenance, in addition to corrosion and irradiation-induced materials degradation
- Long lifetimes and high accumulated fast fluence
  - Mechanical property degradation
  - Cladding swelling
  - Pellet-cladding chemical interaction

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Potential Challenges Associated With Using Current Regulatory Framework

- Regulations geared toward Zr/UO_2 in LWRs, with a nod to steel claddings and metal fuel for SFRs
- Background science is not readily available to make decisions on rules for non-LWR fuels
  - Current public perception and regulatory and business climate preclude "*try it and see what happens*" approaches, common in 1950s to 1970s
  - Current practice (e.g. INPO Zero Leaker guidelines) discourages innovation in commercial reactor that fails any fuel
- Only current option is to build test reactor for given technology and fuel, and extensively experiment in conservative test program

The regulatory and business climate is highly risk adverse, the antithesis of what is needed for innovation

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Non-LWR Fuel Development Will Require Very Long Schedules

- Current LWR fuel development times are 15-30 years, depending on how much operating data is available on materials
  - Licensing approaches are known and guide data generation efforts
  - Test reactors (ATR, Halden, HFIR) available with applicable conditions for testing
  - Knowledge exists of what is important for post irradiation examinations
- New fuel materials and non-LWR conditions could require longer times
  - Licensing approaches not clear, and data requirements may be undefined; adds significant amount of analysis (2-5 years) up front to define key test reactor parameters and data needs
  - Test reactors
    - Lack of test loops with prototypical conditions, adding 10+ years to design, build and start operation of a new test reactor which could then take another 5-10 years for testing
    - Test loops may be available in LWR test reactors but with very low neutron flux in the right energy range, requiring up to 15-20 years to reach desired dpa for high energy neutrons
    - New fast neutron test reactor required for development of fast reactor fuel materials
  - Enrichment: most advanced reactors require >>5%. Challenge for existing commercial fuel enrichment/fabrication facilities

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Long development times and low TRLs make development of new fuels unattractive for fuel vendors

Industry Efforts to Address Challenges on New Fuel Design Licensing

- Great interest by industry to develop and commercialize advanced, high-performance, fuels that would improve safety AND economics of commercial nuclear energy generation
- However, new fuel development is very expensive, risky, and compounded with very long development times, makes any payback uncertain
  - Industry efforts to develop new fuels are minimal unless backed by significant DOE funding

DOE funding is required for ultimate success

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Path Forward: Build Agile Testing Capabilities

- DOE funding for industry is definitely needed along with funding for test facilities
  - Fast reactor with testing loops, including lead, capable of up to 700°C operation for fuel development and testing are required
  - Out-of-pile testing capabilities (e.g. high-temperature flowing lead facilities)
  - Leverage GAIN initiative
- Regulators and DOE need to team and “go back to the future” where test reactors are built in remote locations with reasonable safety analysis to keep costs down and construction time/costs minimal
  - Personnel safety should always be top priority

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Path Forward: Focus Development Efforts on High-Performers

- Advanced reactor and its fuel must promise a significant cost reduction compared to current LWR technology to have any industrial interest
  - Focus on high-performers
- Leverage new fuels being developed by DOE for ATF program
  - SiC and coated cladding and UN fuel
  - High economic and safety performances
- Reward Cross-cutting fuel technologies
  - UN fuel, SiC and coated cladding of interest for nearly all advanced fast reactors

We need to change course from the past. Only more agile testing focused on high-performance products enables commercialization

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