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: corrosion and temperature issues for metal cladding
  - Sodium: temperature an issue for metal cladding
  - Salt: corrosion and temperature issues for metal cladding
  - Gas: no corrosion issues for metals and non-metal cladding, but metals face strength and creep issues at elevated temperatures
- High temperature (400°C to 700°C)
  - Strength and creep for metal cladding
  - Interaction between fuel and cladding
- Low reactor pressure at temperature (1 atmosphere)
  - Internal rod pressure makes stress and creep an issue for cladding materials
- Long lifetimes and high accumulated fast fluence dpa
  - Swelling, potentially leading to cracking

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To some extent, temperature is a design variable and can be selected according to materials availability and expected development.

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 averse, 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 even 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
  - Enrichment: most advanced reactors require >>5%. Existing fuel fabrication facilities cannot handle > 5-10%

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

Industry Efforts to Address Issues and Challenges on Licensing of Concepts for New Fuel Designs

- Industry efforts to develop new fuels are minimal unless backed by significant DOE funding
- Reactor and its fuel must be developed together and must promise a significant reduction in cost as compared to once-through fuel LWRs to have any <u>industrial</u> interest
- Long testing times and substantial upfront expenses (test reactors and testing in them) make a positive return on investment for fuel alone unlikely

DOE funding of test and development facilities, as well as the fuel development effort, is required for success.

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Approaches That Could Work

- DOE funding for industry is definitely needed along with funding for test facilities
- An extensive analytical effort is required up-front to define a workable technology that is economically superior to current LWRs
- 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
- Make use of new fuels being developed by DOE for ATF program

"Innovation in nuclear" can become viable if testing is made more agile…otherwise Innovation will fail.

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