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# Sodium Cooled Fast Reactors (SFR)

## Summary / Objectives:

This webinar will give an overview of distinctive fast reactor characteristics and identify key performance benefits. A brief history of development and international experience with SFRs will be reviewed. Finally, the Generation-IV international collaboration on SFR technology research and development will be described.

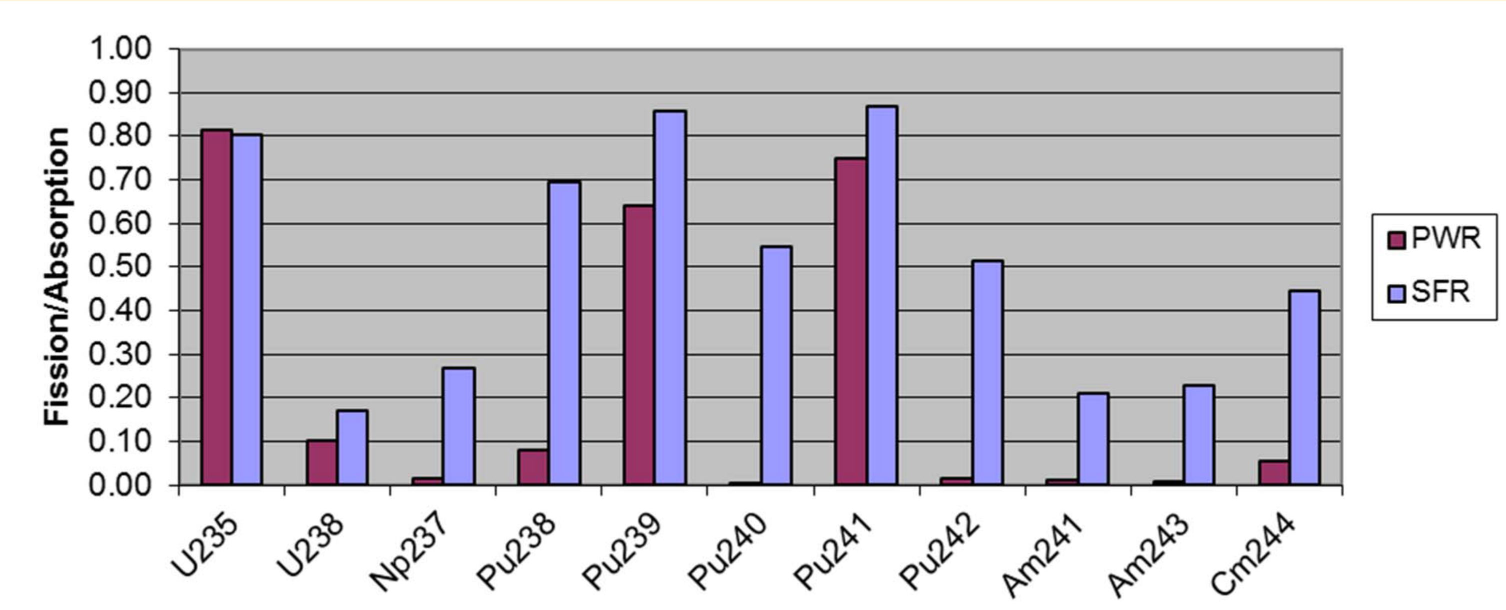
## Meet the Presenter:

**Dr. Robert Hill** is co-National Technical Director for the DOE multi-Laboratory Advanced Reactor Technologies Program; this work includes technology innovation, safety and licensing, advanced materials, energy conversion technology, instrumentation and controls. He also serves as U.S. Member for the Generation-IV Sodium Cooled Fast Reactor and System Integration Project.

**Fuel Cycle Implications of Energy Spectrum :**

Fast reactors are typically intended for closed (recycle) fuel cycle with uranium conversion and resource extension

- Higher actinide generation is suppressed
- Neutron balance is favourable for recycled transuranics (Pu, Np, and Am)




**Uranium Utilization :**

Uranium utilization is one of the benefits of the fast reactor technologies

Through the conventional once-through systems, we have to dispose much amount of depleted uranium on the enrichment process, and total utilization of uranium is about half percent. Recycling the uranium used in fast reactor provides over 90 percent of uranium utilization.

**Once-through systems**

| | PWR-50GWd/t | PWR-100GWd/t | VHTR | Fast Burner |
|---|---|---|---|---|
| Burnup, % | 5 | 10 | 10.5 | 22.3 |
| Enrichment, % | 4.2 | 8.5 | 14.0 | 12.5 |
| Utilization, % | 0.6 | 0.6 | 0.4 | 0.8 |

**Recycling Systems**

| | LWR | | LWR-Fast Burner | | Fast |
|---|---|---|---|---|---|
| | UOX | MOX | LWR-UOX | Fast Burner | Converter |
| Power sharing, % | 90 | 10 | 57 | 43 | 100 |
| Burnup, % | 5 | 10 | 5 | 9 | - |
| Enrichment, % | 4.2 | - | 4.2 | 12.5 | - |
| Utilization, % | 0.7 | | 1.4 | | ~99 |

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**Sodium as a Fast Reactor Coolant :**
Thermophysical and thermal-hydraulic properties of sodium are excellent and allow:

- Use of conventional stainless steels
- Smaller core with higher power density, lower enrichment, and lower heavy metal inventory
- Demonstrated natural circulation and overall passive safety performance
- Use of sodium codified in ASTM standards

| | | |
|---|---|---|
| Thermophysical Properties: | | |
| | Excellent Heat Transfer | ✓+ |
| | Low Vapor Pressure | ✓+ |
| | High Boiling Point | ✓+ |
| | Low Melting Point | ✓ |
| Material Properties: | | |
| | Thermal Stability | ✓+ |
| | Radiation Stability | ✓+ |
| | Material Compatibility | ✓+ |
| Neutronic Properties: | | |
| | Low Neutron Absorption | ✓+ |
| | Minimal Activation | ✓ |
| | Negligible Moderation | ✓+ |
| Supports Passive Safety | | ✓+ |
| Cost: | | |
| | Initial Inventory | ✓+ |
| | Make-Up Inventory | ✓+ |
| | Low Pumping Power | ✓+ |
| Hazards: | | |
| | Sodium reacts with air and water | |

**Worldwide Experience :**
Extensive testing resulted in sodium as the primary coolant in nearly all (land-based) fast reactors constructed during the last 50 years.

| Reactor | Country | MWth | Operation | Coolant |
|---|---|---|---|---|
| EBR 1 | USA | 1.4 | 1951-63 | NaK |
| BR-2 | Russia | 2 | 1956-1957 | Mercury |
| BR-10 | Russia | 8 | 1959-71, 1973-2002 | Sodium |
| DFR | UK | 60 | 1959-77 | NaK |
| EBR II | USA | 62.5 | 1963-94 | Sodium |
| Fermi 1 | USA | 200 | 1963-72 | Sodium |
| Rapsodie | France | 40 | 1966-82 | Sodium |
| BOR-60 | Russia | 50 | 1968- | Sodium |
| SEFOR | USA | 20 | 1969-1972 | Sodium |
| OK-550/BM-40A | Russia | 155 (7 subs) | 1969- | Lead Bismuth |
| BN 350* | Kazakhstan | 750 | 1972-99 | Sodium |
| Phenix | France | 563 | 1973-2009 | Sodium |
| PFR | UK | 650 | 1974-94 | Sodium |
| KNK 2 | Germany | 58 | 1977-91 | Sodium |
| Joyo | Japan | 140 | 1978- | Sodium |
| FFTF | USA | 400 | 1980-93 | Sodium |
| BN 600 | Russia' | 1470 | 1980- | Sodium |
| Superphenix | France | 3000 | 1985-98 | Sodium |
| FBTR | India | 40 | 1985- | Sodium |
| Monju | Japan | 714 | 1994-96, 2010- | Sodium |
| CEFR | China | 65 | 2010- | Sodium |
| PFBR | India | 1250 | 2016? | Sodium |
| BN-800 | Russia | 2000 | 2014- | Sodium |
| ASTRID | France | 1500 | 2025? | Sodium |
| PGSFR | Korea | 400 | 2028 | Sodium |

**Generation-IV R&D Collaboration on SFR :**

Several collaborative Generation-IV R&D Projects are being conducted to explore technology innovations which target to achieve the eight goals for the Generation IV nuclear energy systems

| Criteria | Goal: Generation IV nuclear energy systems will…. |
|---|---|
| Safety and Reliability-1 | *excel in safety and reliability.* |
| Safety and Reliability-2 | *have a very low likelihood and degree of reactor core damage.* |
| Safety and Reliability-3 | *eliminate the need for offsite emergency response.* |
| Economics-1 | *will have a clear life-cycle cost advantage over other energy sources.* |
| Economics-2 | *will have a level of financial risk comparable to other energy projects.* |
| Sustainability-1 | *will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.* |
| Sustainability-2 | *will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden, thereby improving protection for the public health and the environment.* |
| Proliferation Resistance and Physical Protection-1 | *increase the assurance that they are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.* |

**SFR System Research Plan :**

System Research Plan was updated and released in July 2013.
(and further update was conducted in October 2019)

<u>Contents:</u>

<u>*Development Targets and Design Requirements*</u>
<u>*5 SFR R&D Projects*</u>
<u>*4 SFR Design Concepts*</u>