

Status of U.S. Fast Reactor Development

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**IAEA Technical Meeting on Advanced and Innovations in Fast
Reactor Design and Technology**

September 29th – October 3rd 2025, Vienna, Austria

Overview

- U.S. Nuclear Energy Landscape and Public/Private Partnerships
- U.S. Fast Reactor Industry Updates
- U.S. DOE-funded R&D

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US Department of Energy Priorities for Nuclear Energy

Energy Innovation

- Prioritize R&D for affordable, reliable and secure energy technologies
 - Advanced nuclear (among other energy technologies)
- Bolster manufacturing competitiveness and supply chain security

Commercial Nuclear Power

- Lead the commercialization of affordable and abundant nuclear energy
- Enable the rapid deployment and export of next-generation nuclear technology

Peaceful use of nuclear technology and nonproliferation

Recent US Nuclear Developments: 2024 – 2025 Highlights

Reactor Construction and Licensing

TerraPower: Received Wyoming state siting permit; broke ground for construction of non-nuclear facilities in June 2024

Kairos Power: NRC construction permit approved for Hermes demonstration reactor in Tennessee.

X-Energy/Dow: Filed NRC construction permit for Xe-100 deployment in Texas.

Tech and Corporate Investment

Amazon

- \$500M investment in X-Energy; aims for 5 GW SMR capacity by 2039
- Partnering with Energy Northwest on 4 SMRs (320 MW) in Wyoming
- Signed 10-year power purchase agreement with Talen Energy (120 MW increments) for a data center in Pennsylvania

Google

- Will purchase 500 MW from Kairos SMRs by 2035

Microsoft

- 20-year power purchase agreement with Constellation for entire output of Three Mile Island Unit 1 (restart planned by 2028)

Fuel Supply Chain

TRISO-X: Progressing with fuel fabrication facility in Oak Ridge, TN

ORANO-USA: Selected Oak Ridge for new multibillion-dollar enrichment plant

Centrus: Completion of Phase II (900 kg of HALEU) and progressing towards Phase III (3-year extension) could produce 2.7 MTU HALEU per extension period



Current Transportation Shipping Package

(Figure Credit: C. Folkert, “SRNL Meets Nuclear Fuel Need for New Types of Reactors,” Savannah River National Laboratory News Release (2025). Retrieved on April 23, 2025

https://www.srnl.gov/srnl_news/srnl-meets-nuclear-fuel-need-for-new-types-of-reactors/)

DOE-NE is working to make ~22 MTU HALEU available for near-term demonstration needs

- Currently, HALEU is not commercially available in US
- Most reactor vendors are planning reactor demonstration activities in 2025 – 2030
 - Near term: NE can provide HALEU to multiple vendors for demonstration purposes from various domestic stockpiles at various national laboratories
 - Long term: Incentivize domestic market development
 - DOE awarded up to \$800M in contracts to develop US deconversion capacity for advanced nuclear fuels (BWXT, Centrus, Framatome, GE Vernova, Orano, Westinghouse)
 - DOE awarded \$2.7B in HALEU enrichment contracts to four companies to scale domestic HALEU production critical for advanced reactor deployment and energy security (Centrus, General Matter, Orano, Urenco USA)

Source: Various news releases and DOE Office of Nuclear Energy (Uranium Fuel Supply Campaign)



HALEU Allocation

- DOE created HALEU allocation process for vendors to request HALEU material from DOE sources through the HALEU Availability Program
- DOE received requests from 15 companies
- For the first round, five companies received conditional commitments that met prioritization criteria with three requiring fuel delivery by 2025:
 - TRISO-X, LLC
 - Kairos Power, LLC
 - Radiant Industries, Inc
 - Westinghouse Electric Company, LLC
 - TerraPower, LLC
- These companies include Advanced Reactor Demonstration Program (ARDP) Pathway One award recipients, companies planning to demonstrate in the Idaho National Laboratory DOME test bed, and ARDP Risk Reduction awardees.

Source: Department of Energy, "U.S. Department of Energy to Distribute First Amounts of HALEU to U.S. Advanced Reactor Developers," Department of Energy News Release, April 9, 2025. <https://www.energy.gov/articles/us-department-energy-distribute-first-amounts-haleu-us-advanced-reactor-developers>

Figure Credit: National Reactor Innovation Center, Demonstration of Microreactor Experiments (DOME). Retrieved on April 23, 2025 <https://nric.inl.gov/dome/>

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Terrapower GE-H (Sodium)

- Pool-type 345 MWe SFR with molten salt energy storage that can enable 500 MWe during peak demand, based on designs from PRISM and TWR
- Demo will be sited at retiring coal plant site in state of Wyoming; 2021 Infrastructure Investment and Jobs Act provided \$2.477 billion for Sodium and XE-100 demos from 2022-2025.
- HALEU fuel in first reactors (150 MWd/kg); Demo fuel will be metallic U-Zr with sodium bond, advanced fuel will be annular Na-free to enable higher burnup
- Mar. 2024 – Submitted construction permit application to US Nuclear Regulatory Commission (US NRC)
 - Utilizing risk-informed performance-based Licensing Modernization Project (LMP) approach
 - **Approval expected by end of 2025**
- June 10, 2024 – Groundbreaking for non-nuclear portion of Kemmerer Unit 1
- **Jan. 14, 2025 – Received state permit for all construction and operational activities not covered by US NRC**
- **Jan. 21, 2025 – Signed MOU with Sabey Data Centers to develop strategic collaboration agreement to leverage Sodium plants for data centers**
- **May 8, 2025 – US NRC Formalizes Construction Exemption for Sodium Plant Energy Island**



ARC Clean Technology (ARC-100)

- Based on demonstrated technology, 5X scale-up of successfully operated EBR-II.
- 100 MWe, pool-type SFR, inherent safety
- Metallic U-Zr alloy fuel (10.9% to 15.5% enr.) with sodium bond and HT-9 cladding (76.8 MWd/kg)
- 20 year cycle length, once-through cycle is current plan but U/TRU recycle with pyroprocessing is a long term option
- Design considered for Point LePreau Generating Station in New Brunswick, Canada (\$20M grant) with Rankine Cycle; Design also selected for Port Belledune, New Brunswick – Clean Fuels Project for Green Hydrogen Production.
- Recipient of Advanced Reactor Technologies ARC-20 Award; Advanced Design (\$34.4M DOE project at 20% cost-share) will use Brayton cycle with supercritical CO₂ and offer Seismic Isolation
- May 2024 – Signed collaboration agreement with Korea Hydro and Nuclear Power Co. and New Brunswick Power to advance SMR fleet deployment
- **2025 – Completed preliminary design of Gen IV SFR power plant with less than \$30M in public funding**



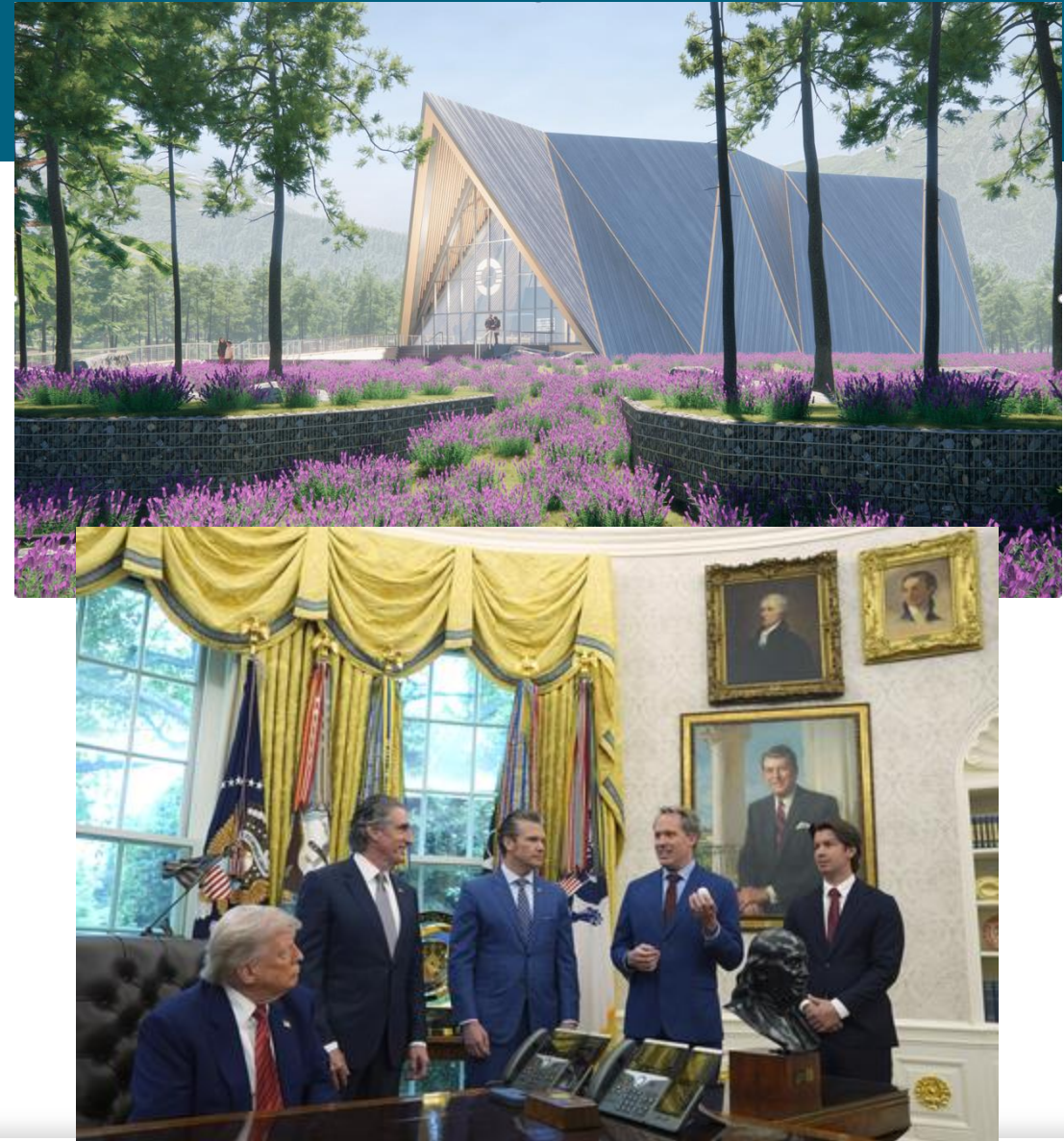
<https://www.arc-cleantech.com/>

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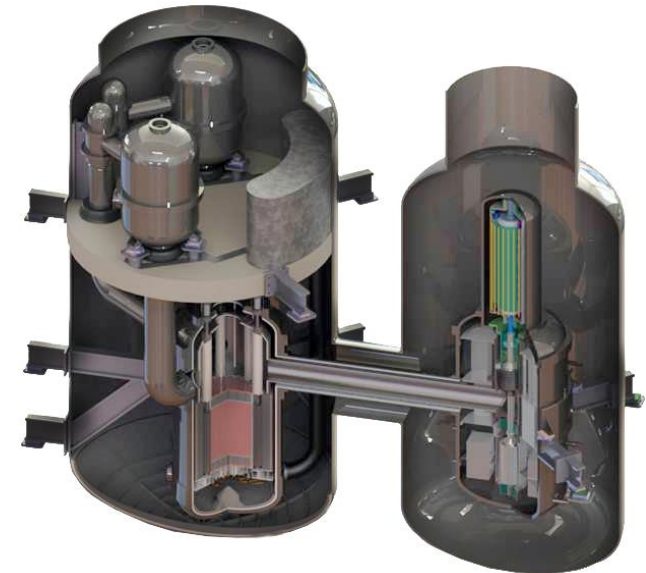
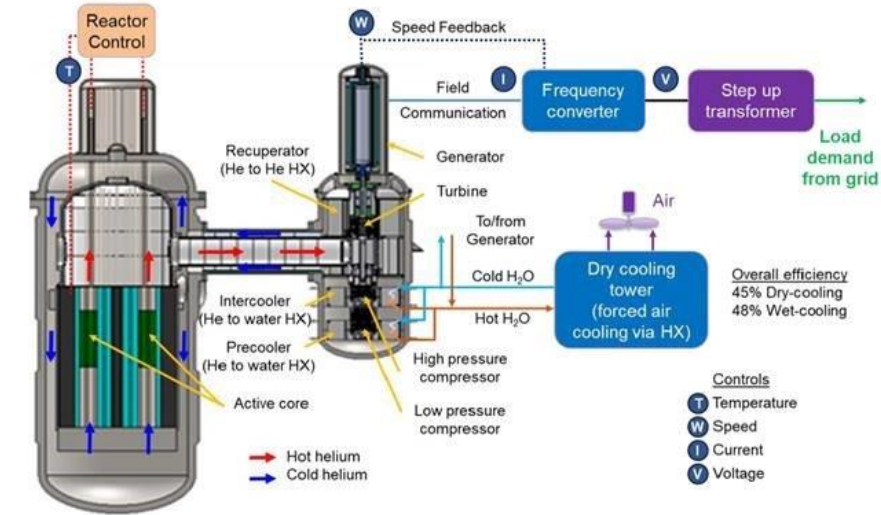
Oklo (Aurora)

- Aurora product line are fast spectrum reactors sized under 100 MWe
- Metallic U-Zr alloy fuel (up to 19.75% enr.) with SS-316 cladding for near-term deployments. Recycled U-TRU-Zr alloy fuel with advanced cladding for longer-term deployments
- Fast spectrum and metallic fuel partly chosen for reuse and recycling potential (<100 MWd/kg for early units, >200 MWd/kg for later ones)
- Received a site use permit from the Department of Energy to site and build its first power plant at Idaho National Laboratory
- Awarded fuel to use in its first reactor in 2019 from recovered EBR-II material, with fuel recovery more than halfway complete.
- May 10, 2024 – After merger with AltC Acquisition Corp, Oklo began trading on the New York Stock Exchange (NYSE:OKLO)
- **Jan. 17, 2025 – Signed MOU with RPower to deploy a phased power model for data centers**
- **June 11, 2025 – Selected as intended awardee to provide power to Eielson Air Force Base in Alaska**



General Atomics GFRs

- Two helium-cooled fast reactor designs, both use direct Brayton cycle to increase efficiency
- Fast Modular Reactor (**FMR**) – 44 MWe
 - Intended to meet demonstration and deployment timelines for near-term introduction into energy market
 - Fuel type uranium oxide pellets with silicon carbide composite cladding
 - DOE-NE ARC-20 award valued at \$31.1M (\$24.8M DOE)
- Energy Multiplier Module (**EM2**) – 265 MWe
 - Designed for rapid construction (road transportable components, factory fabrication, modular construction)
- Update: Fabricated fuel rodlets (SiC composite cladding with UO_2 pellets) that are currently undergoing in-pile irradiation testing at the Advanced Test Reactor



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DOE-NE Fast Reactor Program

Mission Statement

“Anticipate, confirm, and develop the technical elements needed by industry to enable and **sustain** successful large-scale commercialization of fast reactors”

For commercial deployment of fast reactors, stakeholders have identified **two recurring needs:**

- Addressing technical challenges to **reduce capital costs** and improve economic competitiveness
- Providing validated experimental and operational data **supporting fast reactor licensing** cases

High-priority R&D areas:

- Technology Development (sodium experiments, component design and testing)
- Safety and physics software and legacy fast reactor databases
- Development and qualification of advanced structural materials
- International collaborations through bilateral and multilateral agreements
- Train the next generation engineers and scientists through fast reactor R&D

Technical Areas

- **Technology Development**

- Fast reactor component testing and demonstration including use of intermediate-scale sodium loop **METL**
- U.S. fast reactor knowledge preservation

- **Methods, Modeling, and Validation**

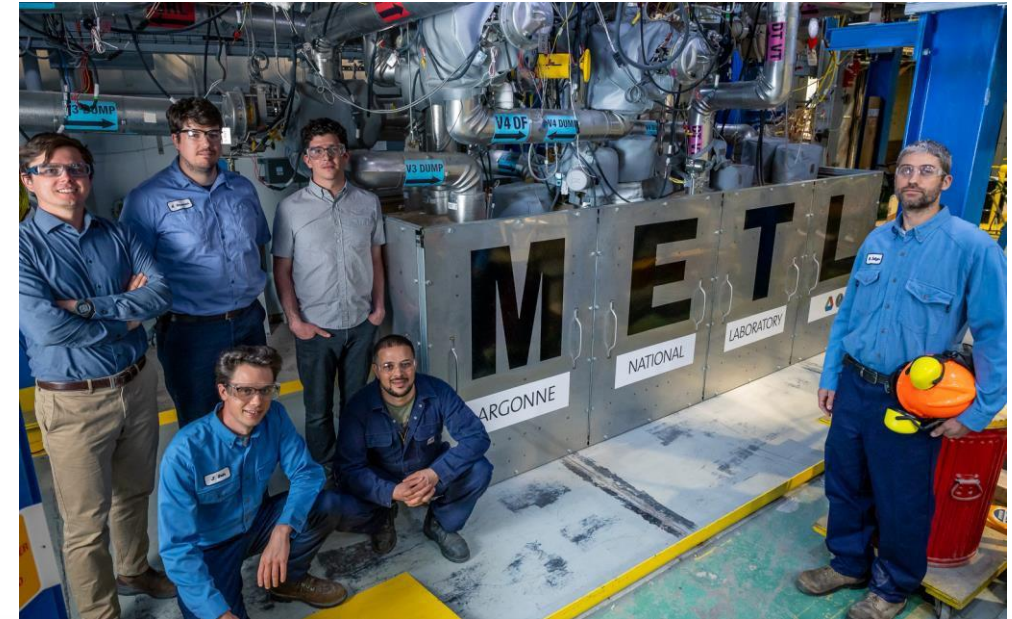
- Developing and maintaining fast reactor **databases** from fuels irradiation and transient testing, reactor safety testing, and component reliability
- Qualification of data and **software** used by industry for design and licensing
- Analysis of old/new **validation** experiments – including test data from **international** collaborations

- **Advanced Materials**

- ASME code qualification of modern alloys – **Alloy 709** for structural materials
- Sodium and material compatibility testing

Technology Development

- **Sodium experimental facility at Argonne National Laboratory to:**
 - Test small or intermediate scale advanced liquid metal components and instrumentation in sodium and
 - Train the next generation of engineers on sodium experiments
- **METL consists of:**
 - ~3,000 kg of reactor-grade sodium – purified in cold trap
 - Two 46 cm test vessels and two 71 cm test vessels (Phase I)
 - Maximum system temperature = 537.8C (except for 71 cm test vessels – 648.9C)
 - Test vessels can be isolated from main loop
- METL has been operational since 2018 while construction/expansion continues (designed for 8 test vessels)

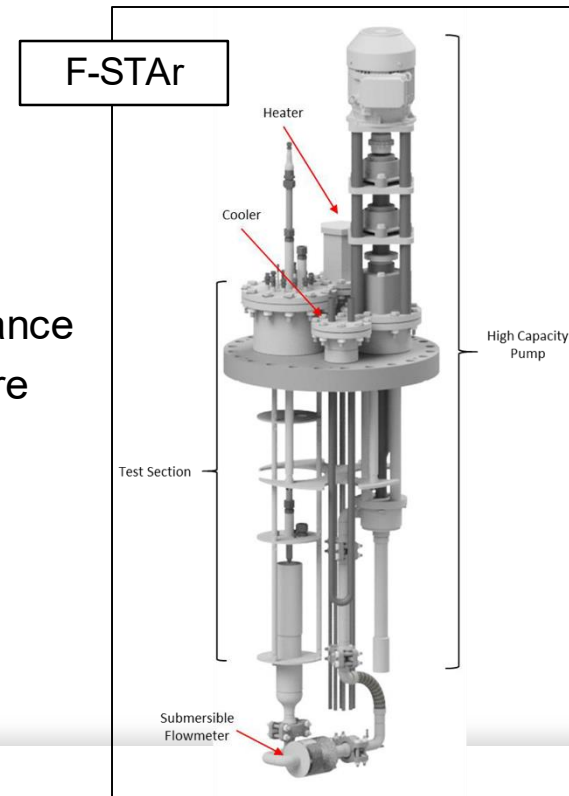
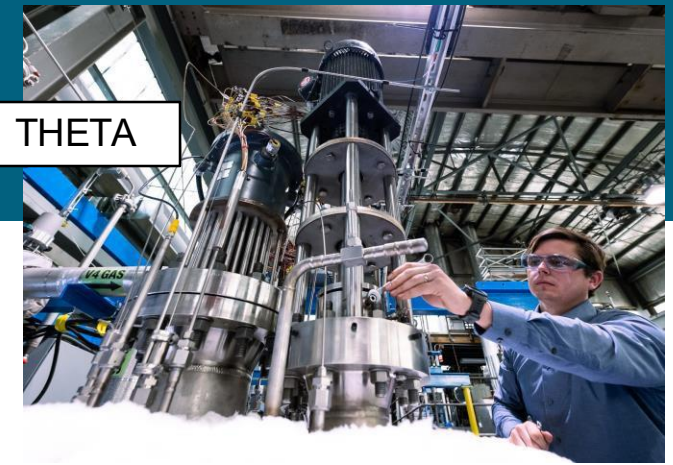


Technology Development

Designing, fabricating, and testing fast reactor component technologies and experiments in METL:

- Gear Test Assembly (GTA)
- Thermal Hydraulic Experimental Test Article (THETA)
- Gripper Test Article (GrTA)
- Flow Sensor Test Article (F-STAr)
- Bearing Test Article (BTA)

These test articles either enable cost reductions and improved performance in SFRs or provide valuable experimental data under sodium for software validation, sensor design, etc.



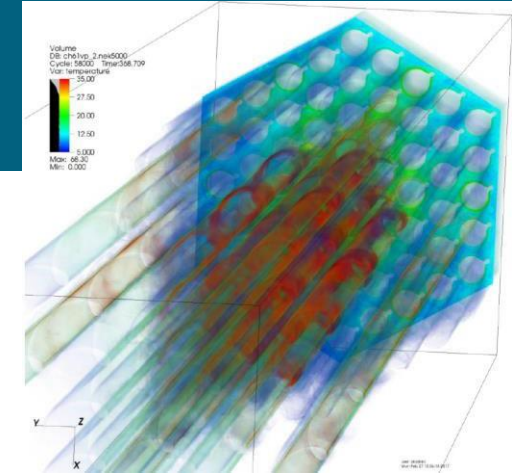
Methods, Modeling, and Validation

Verification and Validation of Fast Reactor Software

- **Examples:** SAS4A/SASSYS-1 (systems/safety) and MFUEL (metallic fuel performance), DIF3D/REBUS (neutronics and fuel management), SRT (source term), SPCA-ANL (sodium fire), etc.
- Industry needs for data and software quality assurance is growing as more license applications submitted to regulator
- Domestic and International fast reactor benchmarks (IAEA, GIF, bilateral agreements)

Collect, organize, and perform quality assurance <https://frdb.ne.anl.gov/>

- EBR-II Shutdown Heat Removal Test (SHRT) database (ETTD)
- FFTF Passive Safety Testing database
- TREAT Test Database (TREXR)
- Fuels Irradiation & Physics Database (FIPD)
- Out-of-Pile Transient Test Database (OPTD)
- Fast Reactor Reliability Database (NaSCoRD)
- Zero Power Reactor Database (ZPRD)



Nek5000 CFD simulation of flow in non-uniformly heated 61-pin assembly

FIPD: Metallic Fuels Irradiation & Physics Database

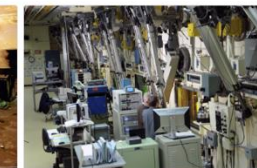
FIPD is an organized collection of metallic fuel test pin data and documentation. The database includes pin operation conditions calculated using a collection of ANL analysis codes developed during the IFR program, including axial distributions for power, temperatures, fluences, burnup, and isotopic densities. The database also contains pin measured data from post-irradiation examination, including pin fission gas release and gas chemistry measurements, and axial distributions from profilometry, gamma scans, and neutron radiography. There is also an extensive collection of documents associated with different pins and experiments, including raw PIE data, design descriptions, safety analysis, and operational reports.



Experiment Operating Data

Browse experiment operational data:

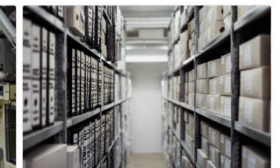
Experiments
Subassemblies
Runs
Pin Designs
Reactor Power/Fission Gas History
Subassembly Coolant Flow Rates



Digitized PIE Collection

Browse digitized PIE by type:

Gas Release
Gas Chemistry
Irradiated Length
Irradiated Weight
Contact Profilometry
Laser Profilometry
Gamma Scan
Neutron Radiography



Document Library

Browse documents by type and content:

Content Types 13
Document Types 11
Posttest Examinations 17
Fabrications 14
Authors 25
Open Literature Resources

Advanced Materials

Code qualifying Alloy 709 to replace 316H stainless steel for SFR structural materials

- Higher creep strength of Alloy 709 can result in decrease in capital cost and increase in safety margins
- R&D effort is planned to accelerate Code qualification timeline by developing technical basis for increasing the time extrapolation of creep rupture data from a factor of 5X to 10X or larger
- Quantify effect of Sodium Exposure on Tensile Strength of Alloy 709 and 316H Stainless Steel in material test loops
- Future: potential examination of impact of neutron irradiation



3rd heat of A709



Creep test frames

Same Starting Point	4-Year mechanical properties and creep testing	100,000-hour ASME, Section III, Division 5 Code Case (Data package ready by Dec. 2024)
	7-year limited creep testing	300,000-hour Division 5 Code Case
	11-year selective creep testing	500,000-hour Division 5 Code Case

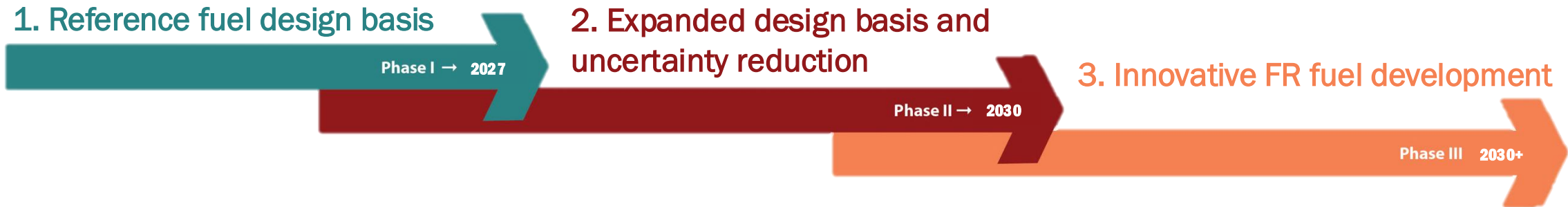
Metallic Fuels Introduction

- Metallic fuel has been developed and utilized, primarily in the U.S., since the beginning of nuclear power technology
 - Desirable attributes make it among most important advanced reactor fuels
 - U.S. strategic technology due to unparalleled EBR-II/FFTF R&D programs, growing interest worldwide



- Metallic fuel for SFRs is a mature technology.
 - U.S. R&D programs since the 1950's
 - Nearly abandoned in the 1960's due to issues with excessive swelling in early life and fast expansion of oxide fuel technology in LWRs
 - Developed as test reactor driver fuel through 1970's
 - Regained focus in Integral Fast Reactor (IFR)-PRISM program in 1980's
 - Modern R&D via the DOE AFC Program, etc. for >20 years
 - Used by all U.S. SFR designers and targeted globally

DOE-NE Advanced Fuels Campaign R&D Goals:



Develop and implement accelerated fuel R&D methodologies and tools.

Phased approach over 5-year period to establish solid foundation, likely parallel to initial deployments.

US LFR Activities

- IAEA CRP NACIE Benchmark (Argonne National Laboratory)
- **DOE Nuclear Energy University Projects (NEUP)**
 - Simultaneous Corrosion/Irradiation Testing in Lead and Lead-Bismuth Eutectic: The Radiation Decelerated Corrosion Hypothesis (MIT)
 - Development of Versatile Liquid Metal Testing Facility for Lead-cooled Fast Reactor Technology (University of Pittsburgh)
- **DOE Technology Commercialization Fund (TCF) projects**
 - SAS4A/SASSYS-1 Improvements for Lead Fast Reactors (Westinghouse/ANL)
 - Enhancement of PyARC for Westinghouse Electric Company's Lead Fast Reactor Design and Modeling (Westinghouse/ANL)

Greyed out = recently completed

Summary

- **There continues to be significant US industry interest in fast reactors**
 - New administration very supportive of advanced nuclear reactors
 - Nuclear energy continues to receive widespread support in the country
 - DOE private/public partnerships – US fast reactor companies making significant progress in deploying demonstrations, with HALEU supply chain being established
 - SFR companies continue to make progress towards licensing and deployment – also significant movement towards utilizing nuclear for data centers
- **Recent progress and accomplishments in fast reactor R&D focused on innovations for performance improvement, cost reduction, and licensing support**
 - METL sodium loop, experiments, and test articles to demonstrate fast reactor technologies
 - Methods validation and databases to support advanced reactor licensing
 - Alloy 709 ASME code qualification for advanced structural materials
 - SFR metallic fuel development, qualification, and irradiation/testing

The background is a collage of various images related to nuclear energy, including nuclear reactors, fuel rods, and workers in protective gear. The images are overlaid with a blue and teal geometric pattern of intersecting lines.

Thank you for your attention

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