Metallic Fuels for Fast Reactors

Summary / Objectives:

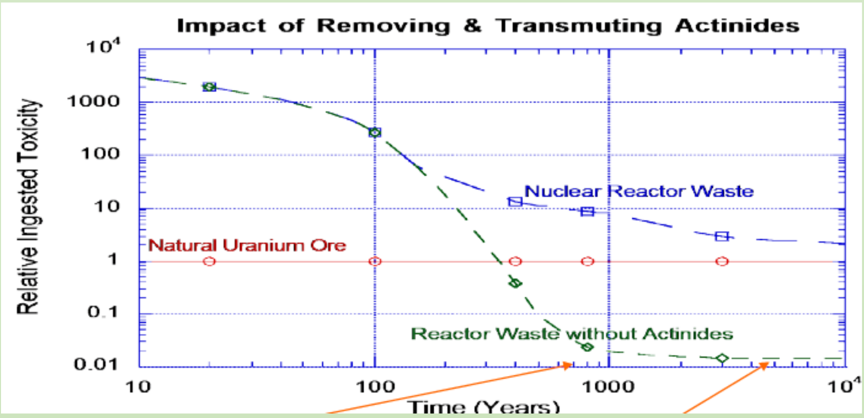
This webinar will provide an overview of metallic fuels used in sodium-cooled fast reactors. Topics to be briefly surveyed will include: a history of metallic fuel development and use; benefits of metallic fuel technology for fuel reliability and safety; and current development directions in the areas of actinide transmutation and ultra-high burnup.

Meet the Presenter:

Dr. Steven Hayes is a Fellow of the Nuclear Science & Technology engaged in the development, testing and modeling of a variety of nuclear fuels, including metallic, oxide, and nitride fuels for liquid metal reactors and high-density dispersion fuels for research reactors. He led numerous fuels and materials irradiation experiments in the Experimental Breeder Reactor II prior to its shutdown, and today he maintains an active fuel testing program in the Advanced Test Reactor. Dr. Hayes is a national leader in the development and testing of metallic fuels for the US-DOE's Advanced Fuels Campaign and in the development of multiscale, multiphysics fuel performance codes for the US-DOE's Nuclear Energy Advanced Modeling and Simulation program.

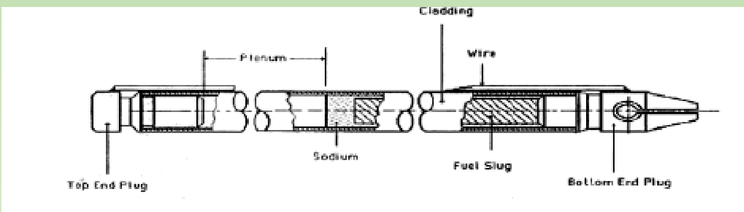
Background: Motivation for Actinide Transmutation

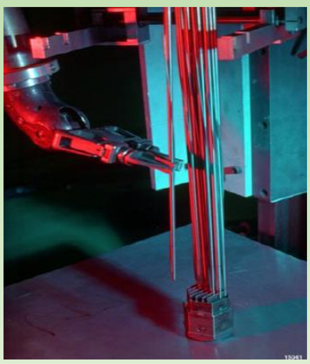
- Plutonium and minor actinides are responsible for most of repository hazard beyond ～400 years.
- Fast reactors are appropriate for actinides transmutation mission, because of large number of excess neutrons, neutrons of high energy, and variety of actinide management strategy.
- SFR Transmutation fuels contain minor actinides and rare earth fission product in significant quantities. So, remote fuel fabrication, new fabrication methods, and determination of effects on fuel performance are necessary.



Metallic Fuels: History & Benefits

- Metallic fuels are used in EBR-1, UK Dounreay Fast Reactor, Enrico Fermi FBR, EBR-II, and FFTF.
- Metal fuels have historical benefit, including reliability to high burnup, compatibility with proliferation-resistant electrochemical recycle, simple and compact fabrication process, and synergistic with passive approach to reactor safety.
- Fabrication of metallic fuels on large scale and remote environments are easy historically. Metallic fuels has demonstrated high-burnup reliability; lower-density alloys for transmutation offer even higher burnup potential.





Casting Process Development

- Traditional casting (Injection casting (counter-gravity)) is employed for remote fabrication of 39,000 metallic fuel pins for EBR-II over a 3-year period in 1960's.
- Application of the traditional casting to metallic transmutation fuels has issues on fuel losses, high level waste, and crucible cleaning and coating.
- New casting process (Bottom casting) was to developed to greatly improve melt utilization, and near-zero Am loss during fabrication.
- Issue of Am volatility during casting has been resolved at bench-scale using surrogate system; validation testing with Am is underway.

Performance of Metallic Fuels with MAs

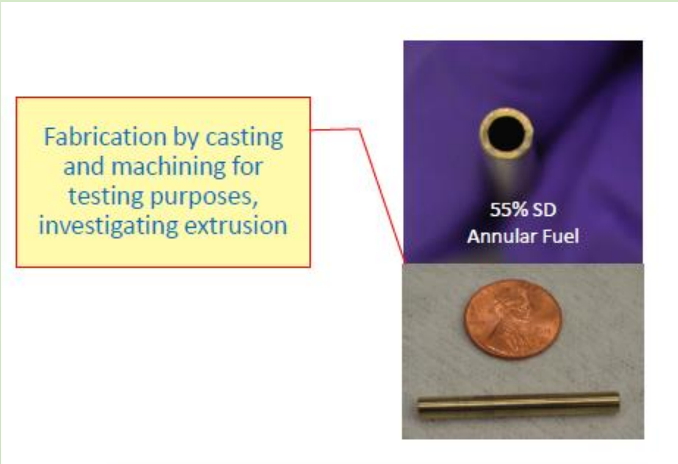
- Wide spectrum of U-Pu-Am-Zr fuel alloys have been conducting in the ATR (AFC-1～4, IRT).
- With double encapsulated testing approach, the tests could be conducted 500W/cm in linear power and 600℃ in cladding temperature.
- Cd-shroud removed thermal neutrons from neutrons of ATR.
- Irradiation performance tested fuels has been shown to be typical of historic understanding for wide variation of U, Pu, Zr, & MA contents.
- Comparison Report (FY17) will validate ATR Cd-shrouded test results vs. data from EBR-II, FFTF, and Phenix.

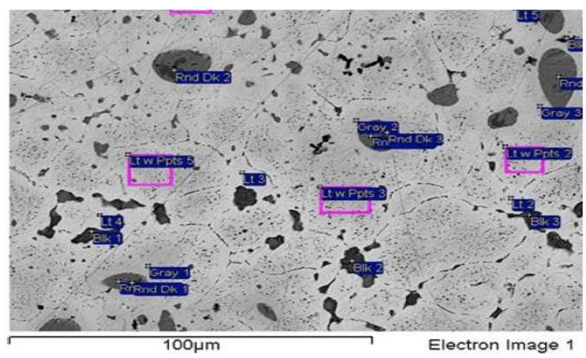
	AFC-1	AFC-2	AFC-3/4	IRT
Test Strategy	Scoping – Many compositions	Scoping – Focused compositions	Focused compositions	Focused compositions
	Nominal conditions	Nominal conditions	Nominal+ conditions	Nominal+ conditions
Capsule Type	Drop-in	Drop-in	Drop-in	Drop-in
Fuel Types	Metallic Nitrides	Metallic Oxides	Advanced Metallic Concepts	Metallic
Key Features	Baseline + MA	Baseline + MA + RE	FP control, annular fuel, FCCI barriers, ultra-high burnup	Recycle feed Remote fabrication
Time Frame	FY 2003 – FY 2008	FY 2008 – FY 2012	FY 2011 – FY 2017 +	FY 2018 – 2020

Past test series   Test series in progress   Future test series

Future Directions: Innovative "Advanced Metallic Fuel Concept"

- Development of the "Advanced Metallic Fuel Concept"
- Additives for Ln FP stabilization and immobilization
- Cladding coating/liners
- Low SD annular fuel, fabrication by extrusion
- Demonstration reliable performance to ultra-high burnups (30-40%)





Back scattered electron image of
U-15Zr-3.86Pd-4.3Ln
(Ln = 53Nd-25Ce-16Pr-6La, in wt%)