U.S. DEPARTMENT OF ENERGY | Nuclear Energy

FC 2: Advanced Fuels

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DOE-NEUP FY2020 Webinar
August 7, 2019

Advanced Fuels Campaign: Structure and Mission

- **Mission:**
  1) Support development of near-term **Accident Tolerant Fuel** (LWR) technologies
  2) Perform research and development on longer-term **Advanced Reactor Fuel** technologies

AFC Advanced Fuels Campaign

Accident Tolerant Fuels

LWR fuels with improved performance and enhanced accident tolerance

Advanced Reactor Fuels

Advanced reactor fuels with enhanced resource utilization for once-through and recycle

Capability Development to Support Fuel Development and Qualification

Advanced characterization and PIE techniques
Advanced in-pile instrumentation
Separate effects testing for model development/validation
Steady-state and transient irradiation testing infrastructure

NEAMS
NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

Fuels Product Line

Multi-scale, multi-physics, fuel performance modeling and simulation

AFC Advanced Fuels Campaign

FY 2019 NEUP Awards

FY 2019 Nuclear Energy University Program R&D Awards				
Title	**Workscope**	**PI Last Name**	**Lead University**	**Total Budget**
Fuel Cycle Research and Development				
Remote laser based nondestructive evaluation for post irradiation examination of ATF cladding	FC-2.1: Post Irradiation Examination (PIE)/Non-Destructive Examination (NDE) Techniques for Corrosion Thickness Measurements on ATF Claddings (Coated Zr, FeCrAl, SiC)	Yu	University of South Carolina	$ 800,000
Radiation-Induced Swelling in Advanced Nuclear Fuel	FC-2.3: Investigations into Non-Traditional Solid Fuels for Advanced Non-Light Water Reactors	Lang	University of Tennessee at Knoxville	$ 799,989
High throughput assessment of creep behavior of advanced nuclear reactor structural alloys by nano/microindentation	FC-2.4: Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications	Mara	University of Minnesota, Twin Cities	$ 800,000
Novel miniature creep tester for virgin and neutron irradiated clad alloys with benchmarked multiscale modeling and simulations	FC-2.4: Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications	Murty	North Carolina State University	$ 800,000
Thermal Conductivity Measurement of Irradiated Metallic Fuel Using TREAT	FC-2.5: Separate Effects Testing in TREAT using Standard Test Capsules	Ban	University of Pittsburgh	$ 500,000
Neutron Radiation Effect on Diffusion between Zr (and Zircaloy) and Cr for Accurate Lifetime Prediction of ATF	FC-2.5: Separate Effects Testing in TREAT using Standard Test Capsules	Zhao	The Ohio State University	$ 499,997

FC 2.1 – NDE Techniques for Assessing Integrity of Coated Cladding Tubes

Federal Manager: Frank Goldner

Technical POC: Tarik Saleh, LANL

- **Near-term Accident Tolerant Fuel (ATF) technologies currently under development include coated cladding concepts**
  - Including coatings on zirconium alloys and SiC-SiC composites
- **Coating thicknesses under development by commercial fuel vendors are typically between 2-20 μm in thickness.**
- **In order to enable and support cost effective manufacturing, non-destructive quality assurance techniques are needed to:**
  - 1) verify the thickness and uniformity of the coating layers
  - 2) identify areas of missing coating layers
  - 3) confirm coating-substrate bond quality.

FC 2.1 – NDE Techniques for Assessing Integrity of Coated Cladding Tubes

- **This call seeks to stimulate proposals to develop and demonstrate *innovative*, *non-destructive*, and potentially *high-throughput* inspection techniques for coated zirconium alloy and/or coated SiC-SiC cladding tubes**
- **Applicants will need to work in collaboration with one or more of the DOE-sponsored ATF vendors (i.e., Westinghouse, General Electric, and Framatome) in order to obtain coated cladding specimens for testing.**
- **Applicants should clearly identify the coating-cladding combination to be investigated and which fuel vendor will supply the applicant with specimens for testing.**
- **The applicant and the fuel vendor are responsible for establishing the intellectual property protection plan for their collaboration and should provide a written confirmation of this established framework in the final proposal.**
- **No portion of the funds in this award area may be used to develop new coating technologies**
- **The focus of the proposal must be on development of useful inspection techniques in support of commercial concepts involved in the ATF program.**

FC 2.2 – Investigations of Carbide and Nitride Fuel Systems for Advanced Fast Reactors

Federal Manager: Janelle Eddins

Technical POC: Andy Nelson, ORNL

- **A wide range of solid fuel advanced fast reactor concepts and their associated fuels are under consideration**
- **U-Zr and MOX fuel have been extensively studied; while UC and UN have seen much less assessment and evaluation**
- **Purpose of this call is to address challenges of UC and UN by leveraging modern experimental methods and modeling and simulation tools**
- **Priority will be given to proposals which include both experimental and modeling and simulation activities**
- **Priority will be given to proposals that address high priority items related to these fuel types such as:**
  - chemical compatibility between UN and Pb coolant
  - compatibility of ferritic-martensitic steels or Al-forming steels with Pb coolant
  - fuel property measurements to fill gaps in existing databases.

Industry Needs for Fast Reactor Fuel Development

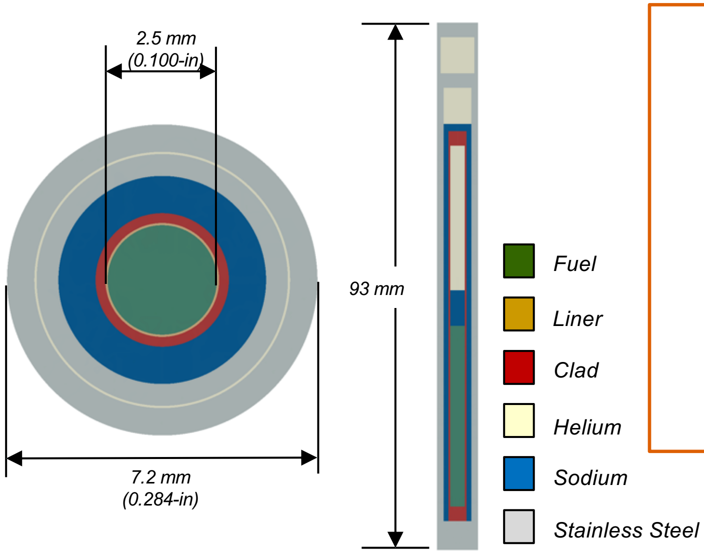
- **GAIN Workshop on Industry Needs**
  - Boise State University, March 5-6, 2019
- **Fuels for Fast Reactors**
  - metallic fuel (SFR, LFR)
  - oxide (LFR)
  - ***nitride (LFR)***
  - ***carbide (GFR)***
  - chloride salt (MSFR)
- **Industry needs:**
  - Thermophysical properties of fresh fuels
  - Quantify degradation of thermal conductivity with burnup, swelling (esp. metallic fuel)
  - Irradiation performance of fuels up to terminal burnups
  - Nitride fuel: irradiation performance, chemical compatibility between liquid lead and UN, UO_2, MOX fuels
  - Carbide fuel: properties and performance data, swelling behavior to high burnup (30%), diffusion and release of fission gas, PCMI between carbide fuel and ceramic (SiC) cladding
  - Cladding:
    - *LFR interest in Al-forming steels, resolving whether FMS can be used in LFRs, interest in coatings or other ways of addressing corrosion-resistance in lead*
    - *GFR interest in SiC*
    - *Data needed on HT9 dose limits and whether is it compatible with lead*

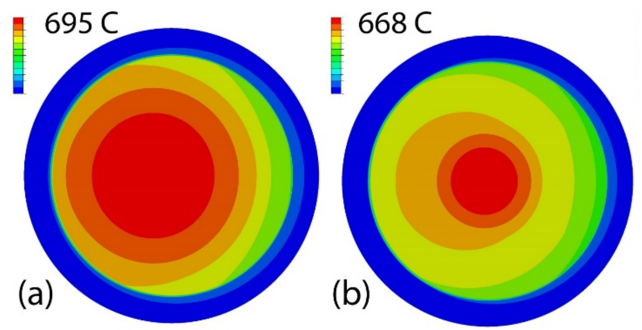
FC 2.2 – Investigations of Carbide and Nitride Fuel Systems for Advanced Fast Reactors

- **Proposals must include:**
  - Brief description of fuel and it's application
  - Which challenge will be addressed, why this challenge is a high priority for the selected fuel and how addressing the proposed challenge will further the development of this fuel
  - Clearly defined research objectives, timelines and deliverables
- **Only proposals addressing UC and/or UN fuel for fast reactor applications will be considered**
- **Only proposals addressing solid fuel for previously-defined fast reactor concepts will be considered**
- **Proposals focused on reactor design activities will not be considered**
- **Irradiation, both neutron and ion beam, are outside the scope of this call**
- **Review previous NEUP awards to ensure proposal is not duplicative**

Accelerated Fuel Testing: FAST (Fission Accelerated Steady-state Testing)

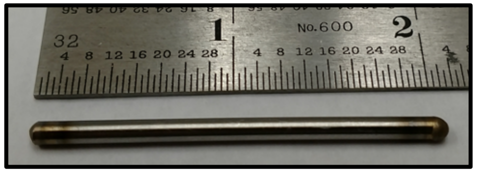
- **Revised Capsule Design Objectives:**
  1) Increase power density to reduce time to achieve high burnup
  2) Decrease fuel diameter to keep peak fuel temperature constant
  3) Reduce sensitivity to fabrication tolerances and capsule/pin eccentricity





Standard vs half diameter (50 μm He gap)
25 μm offset

Fabrication trials for 1/2- and 1/3-scale fuel and rodlets are underway



One-third diameter pins could achieve >5 at.% burnup/ATR 55-day cycle and reach 30 at.% burnup in less than 2 years vs 12 years.

FC 2.3 – High-throughput and/or Micro-scale PIE Techniques to Support Accelerated Fuel Testing

Federal Manager: Ken Kellar

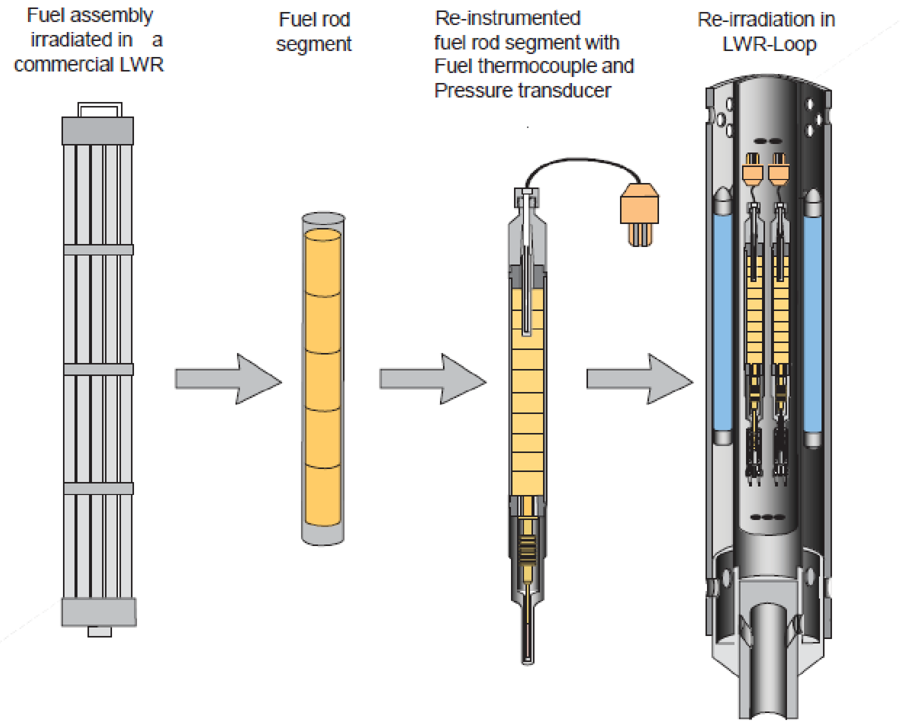
Technical POC: Luca Capriotti, INL

- **There are current activities in AFC to perform irradiation testing of reduced-diameter fuel rodlets to significantly accelerate the burnup accumulation in ATR**
- **This approach creates the need to perform PIE on large numbers of mini fuel rodlets**
  - Challenging to traditional PIE methods relative to timely throughput and reduced dimensional scales
- **Purpose of this call is solicit proposals to develop and demonstrate innovative techniques that can be applied in a hot cell environment**
  - Demonstration using unirradiated, surrogate specimens required
- **Both non-destructive and destructive methods are of interest**
- **Some examples (but not limited to) are measurements of:**
  - Cladding deformation
  - Fuel swelling
  - Fission Gas Release
  - Microstructural characterization of fuel or cladding

FC 2.4 - Maintaining and Building upon the Halden Legacy of In Situ Diagnostics

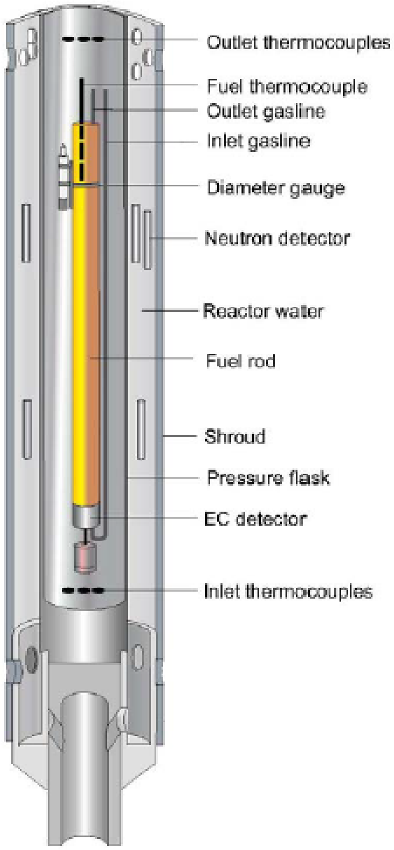
Federal Manager: Ken Kellar
Technical POC: Colby Jensen, INL

- **Halden demonstrated excellence in test specimen manufacture.**
  - Legacy included conversion of large irradiation specimens to smaller instrumented specimens while preserving important features of the test specimen, e.g., the cracked state of irradiated fuel pellets.



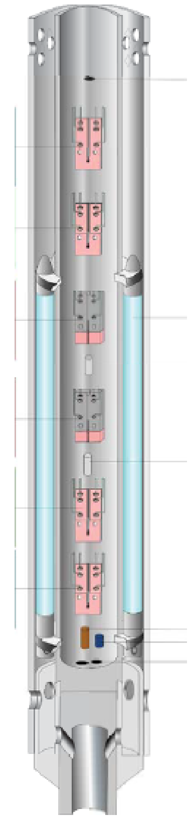
FC 2.4 - Maintaining and Building upon the Halden Legacy of In Situ Diagnostics

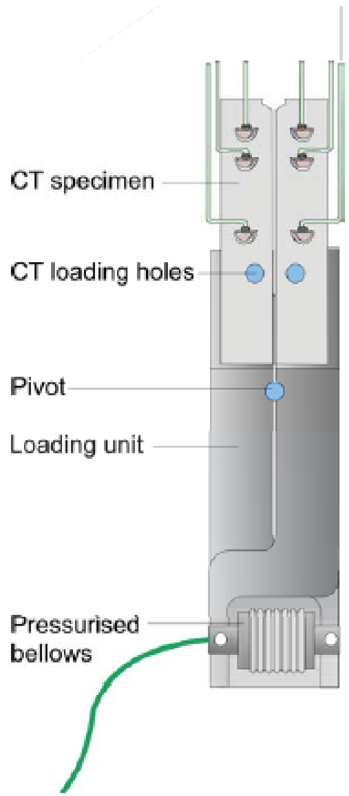
- **Halden experimenters were able to combine multiple diagnostics on one test specimen.**



FC 2.4 - Maintaining and Building upon the Halden Legacy of In Situ Diagnostics

- **Real-time in-core diagnostic instrumentation of interest include, but are not limited to:**
  - creep, crack propagation, swelling, corrosion/crud build up, temperature, pressure, flux, two-flow phase, and fission product transport.
- **Research that enables in-core application and associated logistics is also encouraged such as:**
  - focuses on miniaturization, non-contact/non-intrusive as well as innovative data transmission techniques, such as wireless methods is also encouraged.





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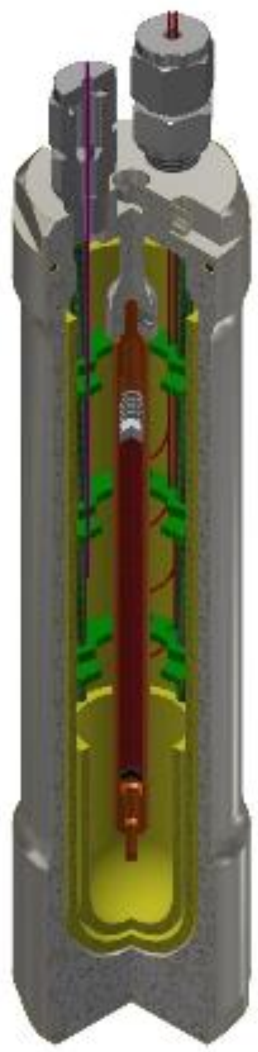
FC-2.5 - Separate Effects Testing in TREAT Using Standard Test Capsules

Federal Manager: Ken Kellar

Technical POC: Dan Wachs, INL

- **ELIGIBLE TO LEAD: UNIVERSITY ONLY**
- **UP TO 3 YEARS AND $500,000**
- **NSUF ACCESS REQUEST REQUIRED**



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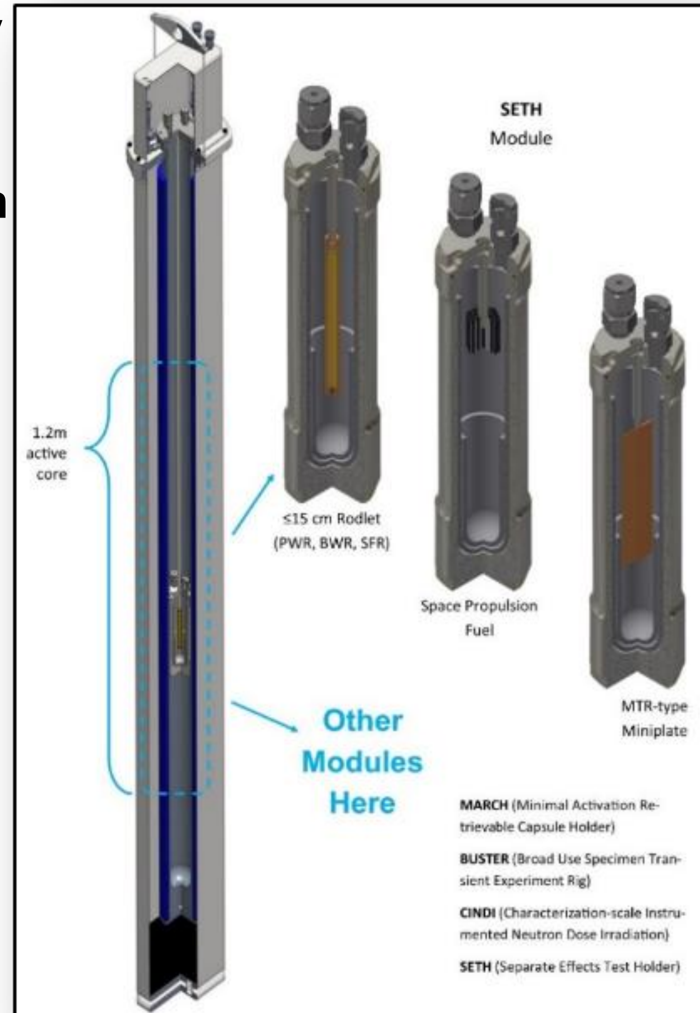
Micro-scale Interest

- **DOE is seeking nuclear fuel development strategies that rely on integration of micro-scale material science and thermal-mechanical engineering through advanced modeling and simulation techniques.**
- **Interest in developing the physical models input into the codes as well as the integral system data to be used in validating the result of the simulations.**



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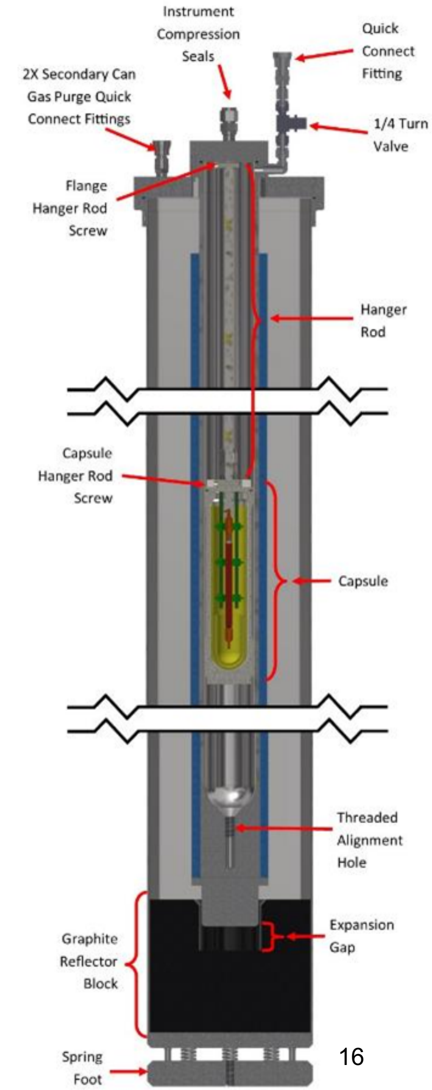
TREAT Use

- **Proposals are sought that will leverage TREAT's Minimal Activation Reusable Capsule Holder (MARCH) irradiation testing system and modern modeling and simulation tools to conduct novel separate effects tests.**



TREAT and IMCL

- **Test vehicles:**
  - MARCH-SETH (dry)
  - MARCH-SERTTA (liquid)

- **Examples may include:**
  - In-situ evaluation of physical properties of fissile material while under irradiation
  - Thermal-mechanical response of fuel system components to nuclear heating
  - Short-term microstructural evolution of fissile materials under irradiation.

- **TREAT and IMCL**
  - The Irradiated Materials Characterization Laboratory is expected to be used in conjunction with TREAT experiment preparation and PIE.

- **Proposers should contact INL early to ensure the proposed scope is compatible with the NSUF facilities.**

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Contact Information

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  - Dan Wachs (INL), daniel.wachs@inl.gov
- **Please review previous fuel related awards at www.neup.gov.**

Advanced Fuels Campaign

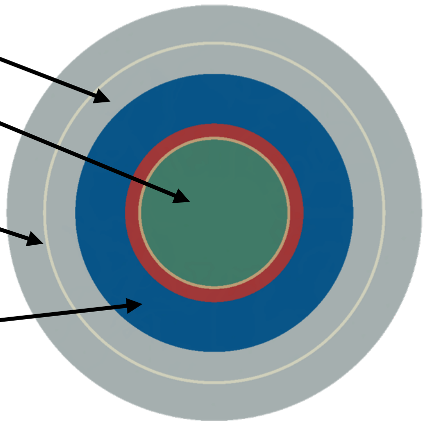
NEUP Nuclear Energy University Programs

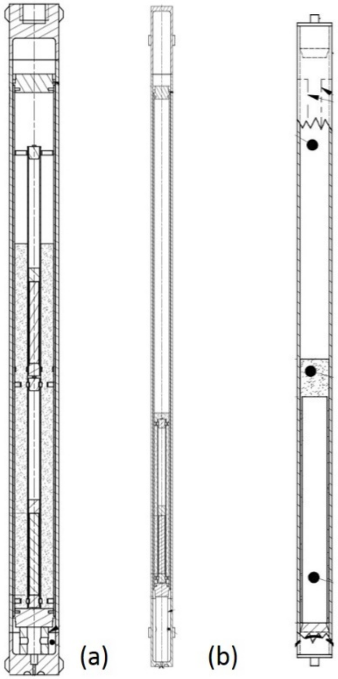
U.S. Department of Energy

Background Information

Approach for Capsule Design

- Introduce a second, inner capsule
- Reduce fuel diameter with similar LHGR
- Use pressurized helium gap (~500 psi at room temperature) between capsules to reduce uncertainties
- Sodium bond the rodlet to the inner capsule





The basic approach is to reduce fuel pin diameter, increase fuel power density, and push the He gap far away

Advanced Fuels Website

https://nuclearfuel.inl.gov/afp/SitePages/Home.aspx

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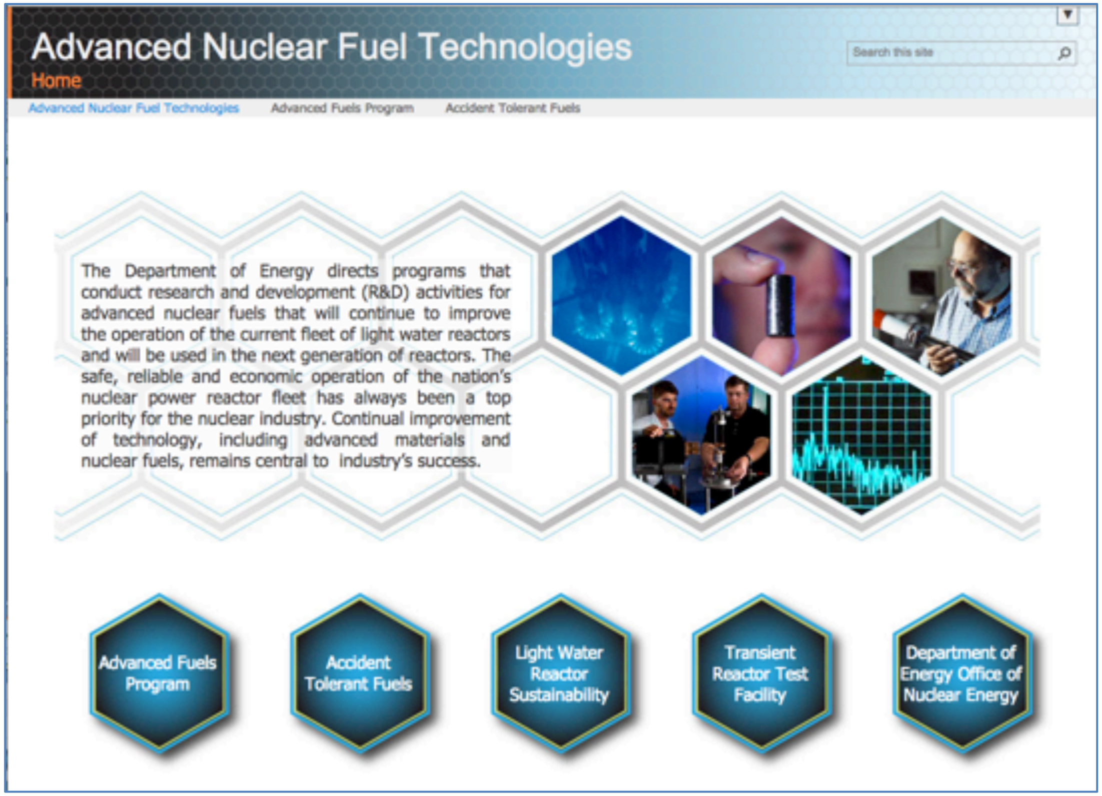

Accident Tolerant LWR Fuel Information Sheet

Advanced Fuels Campaign

NEUP Nuclear Energy University Programs

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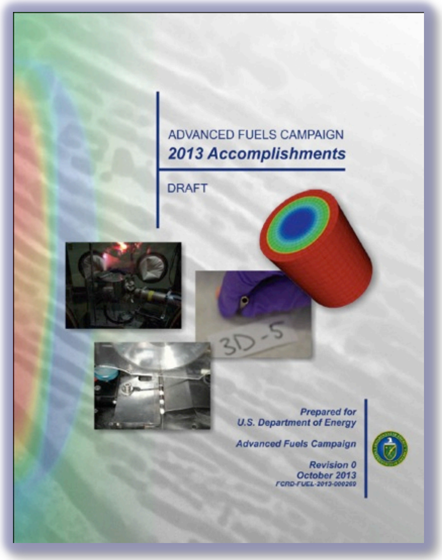
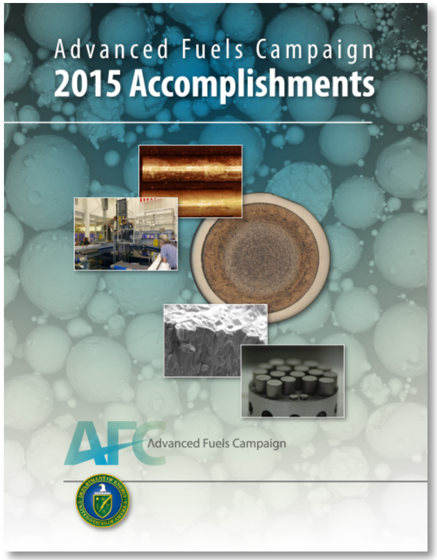
Recent Advanced Fuels Campaign Documents – Available on OSTI

OSTI Document Links of Interest:

Overview of Accident Tolerant Fuel Program
http://www.osti.gov/scitech/servlets/purl/1130553

Accident Tolerant Fuel Performance Metrics
http://www.osti.gov/scitech/servlets/purl/1129113





Advanced Fuel Cycle Web Site:
https://nuclearfuel.inl.gov/afp/SitePages/Home.aspx

2018 Accomplishments Report
https://nuclearfuel.inl.gov/afp/flipbook/index.aspx?page=1