U.S. DEPARTMENT OF ENERGY | Nuclear Energy

FC 2: Advanced Fuels

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DOE-NEUP FY2018 Webinar
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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 for enhanced resource utilization

Capability Development to Support Fuel Development and Qualification
Advanced characterization and PIE techniques
Advanced in-pile instrumentation
Separate effects testing for model development/validation
Transient testing infrastructure

NEAMS
NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

Fuels Product Line
Multi-scale, multi-physics, fuel performance modeling and simulation

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FY 2018 NEUP Awards

FY 2018 Nuclear Energy University Program R&D Awards			
Title	**Area**	**PI Last Name**	**Lead University**
Bridging the length scales on mechanical property evaluation	FC-2.1	Hosemann	University of California, Berkeley
Benchmarking Microscale Ductility Measurements	FC-2.1	Kingstedt	University of Utah
Bridging microscale to macroscale mechanical property measurements and predication of performance limitation for FeCrAl alloys under extreme reactor applications	FC-2.1	Wang	University of Nebraska, Lincoln
Microstructure-Based Benchmarking for Nano/Microscale Tension and Ductility Testing of Irradiated Steels	FC-2.1	Wharry	Purdue University
Radiolytic Dissolution Rate of Silicon Carbide	FC-2.3	Bartels	University of Notre Dame
Understanding of degradation of SiC/SiC materials in nuclear systems and development of mitigation strategies	FC-2.3	Hosemann	University of California, Berkeley
Development of Multi-Axial Failure Criteria for Nuclear Grade SiCf-SiCm Composites	FC-2.3	Huang	University of South Carolina
Probabilistic Failure Criterion of SiC/SiC Composites Under Multi-Axial Loading	FC-2.3	Le	University of Minnesota, Twin Cities
Advanced Coating and Surface Modification Technologies for SiC-SiC Composite for Hydrothermal Corrosion Protection in LWR	FC-2.3	Sridharan	University of Wisconsin-Madison
Multiaxial Failure Envelopes and Uncertainty Quantification of Nuclear-Grade SiCf/SiC Woven Ceramic Matrix Tubular Composites	FC-2.3	Subhash	University of Florida
Mechanistic Understanding of Radiolytically Assisted Hydrothermal Corrosion of SiC in LWR Coolant Environments	FC-2.3	Was	University of Michigan

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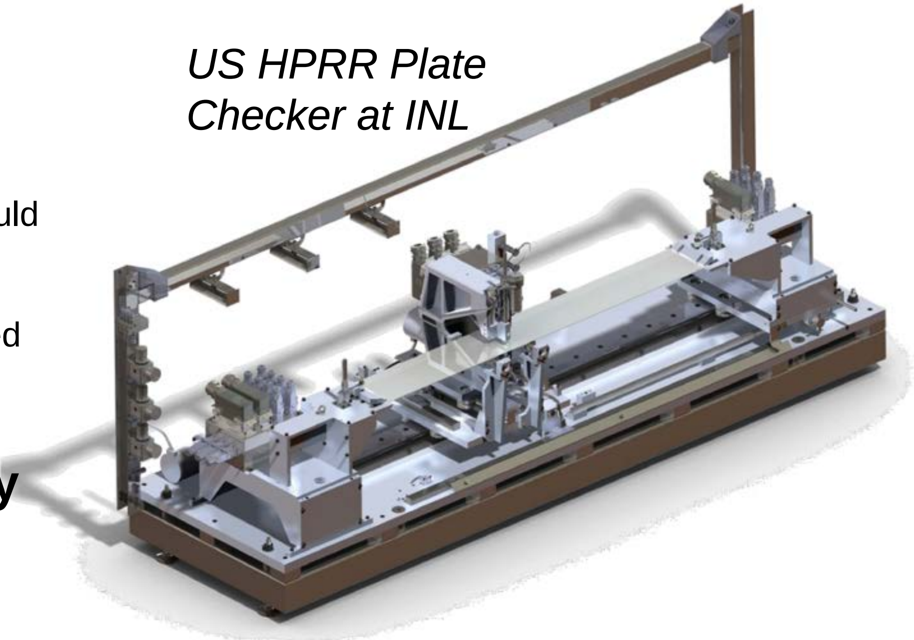
FC 2.1 – Post Irradiation Examination (PIE)/Non Destructive Examination (NDE) Techniques for Corrosion Thickness Measurements on ATF Claddings (Coated-Zr, FeCrAl, SiC) (1)

Federal Manager: Frank Goldner
Techical POC: Jason Harp (INL)

- **Proposals are solicited for techniques or a suite of techniques that can be applied to evaluate the surface oxide, surface layer adhesion and sub-surface features, such as micro-cracks and delamination, for a wide variety of accident tolerant cladding concepts.**
- **Techniques developed should be demonstrated to work in a**
  - Remote, high radiation environment
  - Signals from the demonstrated techniques should travel greater than 30 feet from sensor to data collection equipment
  - Signals must pass through a hermetically sealed feedthrough
- **Collaboration with existing ATF cladding vendors will be favorably viewed**

US HPRR Plate Checker at INL



Advanced Fuels Campaign

FC 2.1 Post Irradiation Examination (PIE)/Non Destructive Examination (NDE) Techniques for Corrosion Thickness Measurements on ATF Claddings (Coated-Zr, FeCrAl, SiC) (2)

- **Current Program Focus:**
  - Accident Tolerant Fuel Cladding concepts that support needs of proposed accident tolerant candidate concepts prioritized by the industry (Coated-Zr, FeCrAl, SiC)
  - This work is intended to support national lab development and testing capabilities in preparation of initiating PIE on ATR irradiated and TREAT irradiated cladding samples
- **Coating adhesion and oxide layer thickness need to be evaluated for ATF cladding.**
  - The in-pile corrosion and adhesion properties of coated Zr are not currently known.
  - A non-destructive technique that evaluates coating adhesion and oxide layers over a significant portion of the cladding surface is desired.
  - Ideally the developed technique would also be compatible with FeCrAl alloys
  - Composites of SiC are also being investigated and these composites generate very thin oxide layers in pressurized water conditions. The SiC-based cladding concepts also can contain various sub-surface interfaces and the integrity and damage accumulation at those interfaces will be a performance aspect that must be examined and quantified.
- **The oxide layer on zirconium alloys has typically been evaluated with Eddy Current.**
  - This technique typically requires a new set of sensors for every new substrate, and the response of eddy current sensors to ferritic substrates is quite different from non-ferritic substrates.
  - This technique is also only applicable to conductive substrates. Presently, eddy current also cannot distinguish between voids (lack of adhesion) and oxide growth.
- **Priority will be given to applications that clearly support near-term needs of existing ATF industrial application concepts and are scalable to full length rods. Remote hot-cell application experience in the collaboration team will also be given priority.**

FC 2.2 – Studies on Accident Tolerant Control Rods and Core Components (1)

Federal Manager: Frank Goldner

Technical POC: Michael Todosow (BNL)

- **The Advanced Fuels Campaign is currently investigating fuels and cladding with enhanced accident tolerance (aka Accident Tolerant Fuels - ATF) for implementation in commercial light-water reactors (LWRs). However, retention of “functionality” of other core components (e.g., control rods) is also critical to successfully surviving/limiting the consequences of Beyond Design Basis Accidents (BDBAs), as well as normal operation, Anticipated Operational Occurrences (AOOs) and Design Basis Accidents (DBAs).**
- **Current Program Focus:**
  - In response to the accident at the Fukushima Daichi nuclear power plant, a significant effort was initiated by the Department of Energy, Office of Nuclear Energy (DOE-NE) in the Advanced Fuels Campaign (AFC) to develop fuels with enhanced accident tolerance.
  - Experiments and analyses have been underway to identify, characterize, and address the impact of candidate ATF fuel and/or cladding concepts on reactor performance and safety characteristics, AOOs, DBAs, and BDBA.
  - Our current focus is on concepts identified, and being pursued by three industry teams with plans targeting insertions of Lead Rods (LRs) in commercial LWRs in the next 1-2 years

FC 2.2 – Studies on Accident Tolerant Control Rods and Core Components (2)

- **Proposals are sought that consider the neutronic, and thermo-mechanical impacts of potential future advanced materials for BWR and PWR control rods that retain/enhance the poisoning effects/requirements (worth – individual and bank, etc.) while maintaining structural integrity/functionality (e.g., ability to insert/ withdraw) during normal operation and accident conditions (temperatures, cooling, etc.).**
- **Also, materials and associated studies are sought that address retention of the structural integrity/geometry of the core which depends on the ability of components such as grid spacers, core support plate, etc., to retain "functionality" during normal operation and accident conditions.**
- **Proposals must indicate recognition of existing DOE-NE ATF related programs in this area.**

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FC 2.3 – Investigations into Non-Traditional Solid Fuels for Advanced non-Light Water Reactors (1)

Federal Manager: Janelle Eddins

Technical POC: Andy Nelson (ORNL)

- **A wide range of advanced reactor concepts and their associated fuels are under consideration**
- **Some fuel types have been extensively studied such as U-Zr metallic fuel, oxide fuel types and traditional TRISO (UO2, UCO); while other advanced fuel types have received limited study**
- **Purpose of this call is to address challenges of lesser known and novel fuels by leveraging modern experimental methods and modeling and simulation tools**
- **Fuel concepts proposed should support one or more of the following reactor designs:**
  - HTGRs/VHTRs, FHRs, LFRs, GFRs, SFRs
- **Irradiation testing (if applicable to the area of study) and PIE are advantageous but not required**
  - Use of ion beam irradiation is an option where applicable
- **Priority will be given to proposals which include both experimental and modeling and simulation activities**

FC 2.3 – Investigations into Non-Traditional Solid Fuels for Advanced non-Light Water Reactors (2)

- **Proposals must include:**
  - Brief description of fuel and its application
  - Which challenge will be addressed and how addressing the proposed challenge will further the development of this fuel
  - Clearly defined research objectives, timelines and deliverables
- **Examples of fuels that will be considered**
  - Less studied fuels such as U-Mo, UC, UN, etc.
  - TRISO-like and/or encapsulated fuel particle research beyond traditional UO2,UCO
    - *Alternative fuel kernels (UN, UC, MOX, TRU), different coating and matrix materials besides SiC and graphite, novel TRISO fuel and its chemical/corrosion compatibility for use in coolants other that water or helium, TRISO-like or particle fuel for GFR applications, etc.*
- **Fuels that will not be considered**
  - Well studied and developed fuels such as U-Zr, MOX, traditional TRISO fuel (UO2, UCO) for thermal spectrum helium cooled HTGRs
  - Thorium based fuel concepts
  - Light water reactor fuels including ATF concepts
- **Proposals focused on reactor design activities will not be considered**

FC 2.4 – Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications (1)

Federal Manager: Janelle Eddins

Technical POC: Stuart Maloy (LANL)

- **Long term use of fuels for advanced reactors can lead to thermal and irradiation creep of fuel cladding and other stressed structures**
- **Creep can contribute to dimensional changes under accident conditions in LWRs**
- **Typical out of pile thermal creep testing requires long times (many years) and large sized specimens**
- **Significant testing has been performed to measure creep of HT-9, ODS ferritic alloys and traditional Zr cladding for LWRs**

FC 2.4 – Advanced Creep Testing of Ferritic Steels for Reactor Cladding Applications (2)

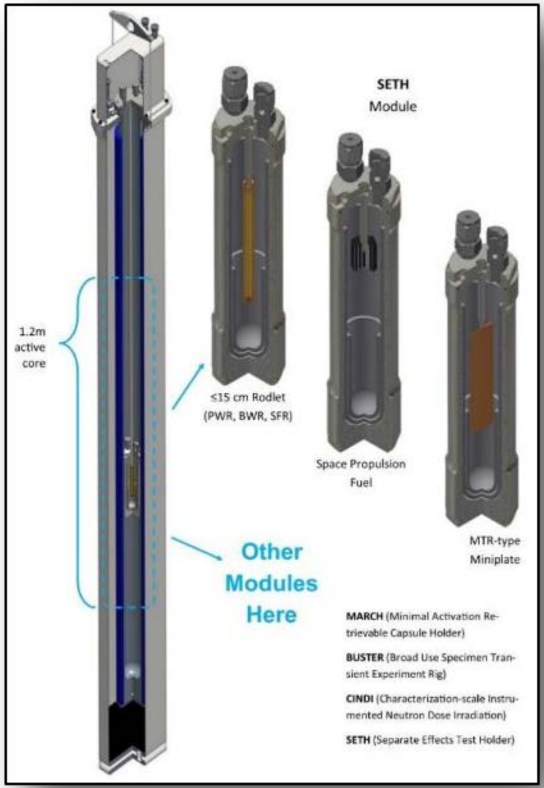
- **Purpose of this call is two-fold:**
  - Develop improved methods for measuring thermal creep requiring shorter evaluation times and possibly smaller scale specimens
  - Use developed method to measure creep and provide data for new alloys for cladding applications such as FeCrAl, ferritic ODS alloys or tempered martensitic alloys
- **Priority given to proposals that show how the data will be incorporated into relevant multi-scale models**
- **It is advantageous but not required that the proposed method can also be used to measure irradiation creep in situ**
- **For LWR fuel cladding, only ATF concepts of interest to the Advanced Fuels Campaign will be considered**
- **For Advanced Reactor cladding, tempered martensitic steels, ferritic ODS alloys and innovative new metal alloys will be considered**

FC-2.5: SEPARATE EFFECTS TESTING IN TREAT USING STANDARD TEST CAPSULES

- FEDERAL POC: KEN KELLAR & TECHNICAL POC: DAN WACHS
- ELIGIBLE TO LEAD: UNIVERSITY ONLY
- (UP TO 3 YEARS AND $500,000)
- (NSUF ACCESS REQUEST REQUIRED)

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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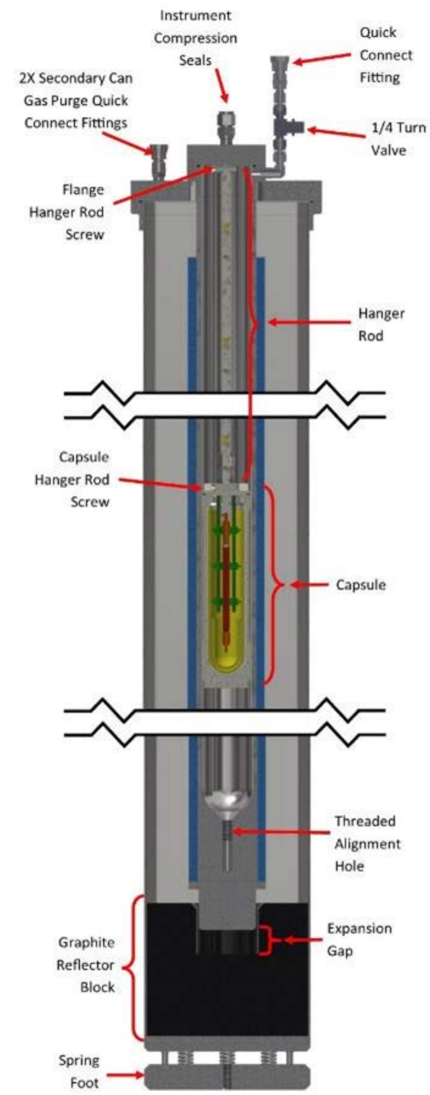
TREAT Use

- **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.**



Advanced Fuels Campaign

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.**

Contact Information

- **AFC National Technical Director:**
  - Steve Hayes(INL), steven.hayes@inl.gov
- **Federal Program Managers:**
  - Frank Goldner, frank.goldner@nuclear.energy.gov
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  - Ken Kellar, kenneth.kellar@nuclear.energy.gov
- **Technical Leads:**
  - Jason M Harp (INL), jason.harp@inl.gov
  - Michael Todosow (BNL), todosowm@bnl.gov
  - Andy Nelson (ORNL), nelsonat@ornl.gov
  - Stuart Maloy (LANL), maloy@lanl.gov
  - Dan Wachs (INL), Daniel.Wachs@inl.gov
- **Please review previous fuel related awards at www.neup.gov.**

Background Information

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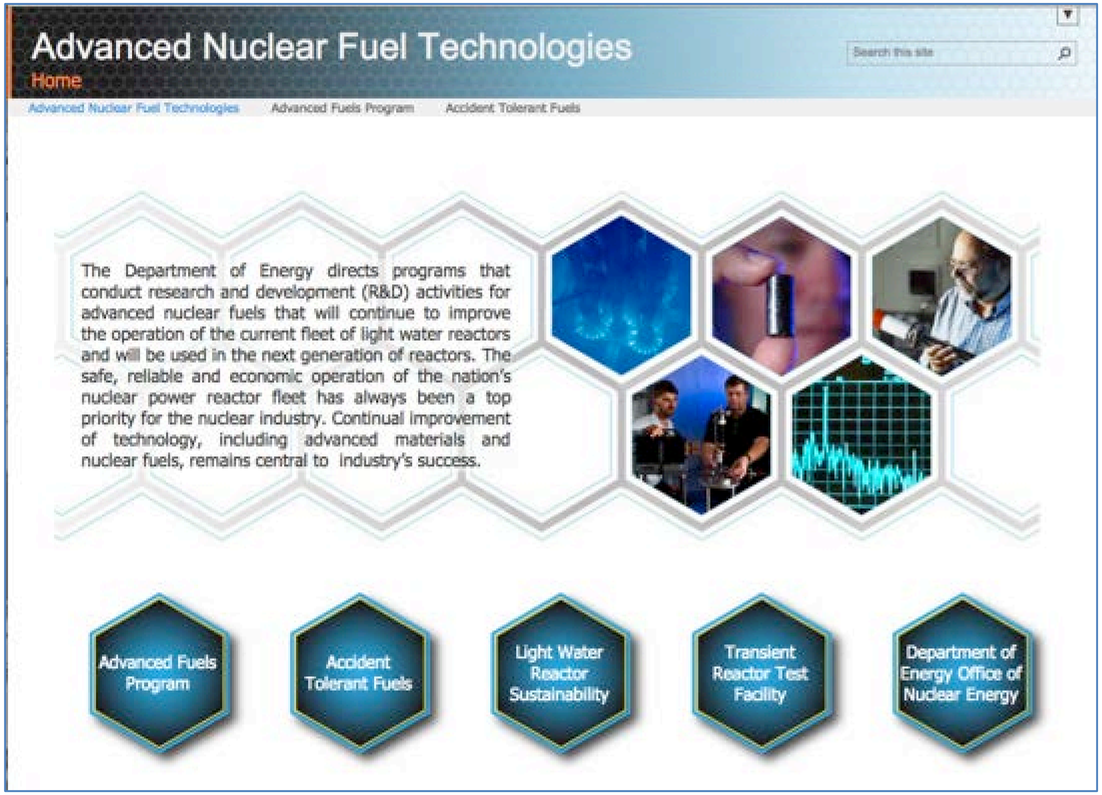
Advanced Fuels Website
https://nuclearfuel.inl.gov



Accident Tolerant LWR Fuel Information Sheet


ENERGY | Nuclear Energy
Advanced Nuclear Fuels

Enhanced Accident Tolerant Fuels for Light Water Reactors

Development Goal: Demonstrate performance by inserting a lead test rod or lead test assembly into a commercial power reactor by 2022 with deployment in the U.S. light water reactor fleet to follow within 20 years.

Current LWR Fuel

ATF Program Goals

(Continued)

Enhanced Tolerance to Loss of Active Core Cooling

Improved Reaction Kinetics with Steam

Improved Cladding Properties

Improved Fuel Properties

Enhanced Retention of Fission Products

Advanced Fuels Campaign

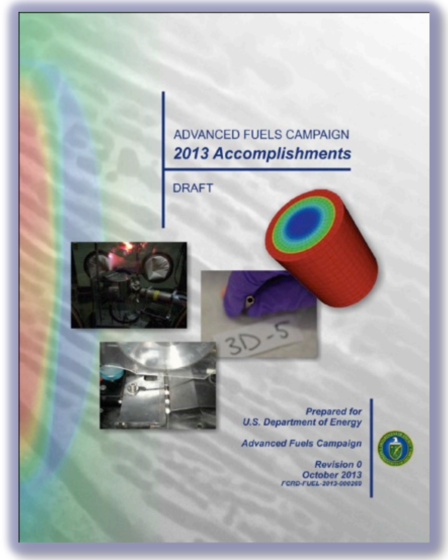
NEUP Nuclear Energy University Programs
U.S. Department of Energy

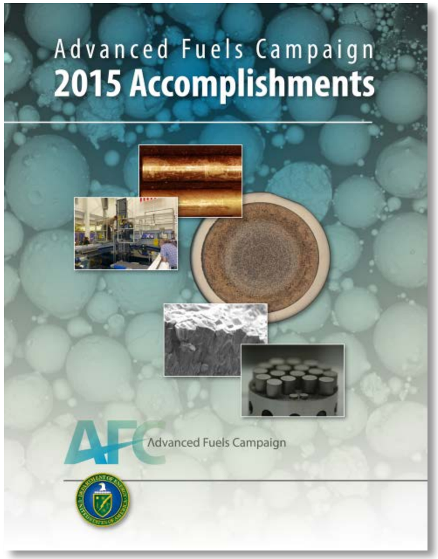
Recent Advanced Fuels Campaign Documents – Available on OSTI

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

2017 Accomplishments Report
https://nuclearfuel.inl.gov/afp/AFC%20Accomplishments%202017/index.aspx?page=1