Advanced Fuels Campaign

Office of Nuclear Energy

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National Technical Director
Advanced Fuels Campaign
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The FCRD Advanced Fuel Campaign is tasked with development of near term accident tolerant LWR fuel technology and performing research and development of long term advanced reactor fuel options.

- Advanced LWR Fuels with enhanced performance, safety, and reduced waste generation
- Advanced reactor fuels with enhanced proliferation resistance and resource utilization
- Multi-scale, multi-physics fuel performance modeling and simulation
- Capability Development for Science-based Approach to Fuel Development
  - Advanced characterization and PIE techniques
  - Advanced in-pile instrumentation
  - Separate effects testing
  - Transient testing infrastructure
AFC High Level Technical Objectives (5-year)

- Identify and select advanced LWR fuel concepts for development towards lead test rod testing by 2022.
- Support the near term qualification and sourcing of driver fuel for near-term test and demo reactors.
- Complete the conceptual design for the baseline advanced reactor fuel technologies with emphasis on the fundamental understanding of the fuel fabrication and performance characteristics for recycle fuels.
- Achieve state-of-the art infrastructure that can be used to perform fuel research and development from a “science-based” approach accelerating further development of selected concepts.
- Integrate with the development of the predictive, multi-scale, multi-physics fuel performance code.
Integrating DOE and Industry Efforts

High Performance Accident Tolerant LWR Fuels
- Accident tolerant
- Ceramic and chromium coated zircalloys
- Multi-layer ceramic claddings
- High density ceramics
- High thermal performance

Fast Reactor Fuels
- Advanced manufacturing
- Actinide bearing
- Advanced performance

High Temperature Gas Reactor Fuels
- TRISO based fuel
- High burnup – high temperature
- Multi-layer fission production retention

DOE AFC is providing the U.S. nuclear industry with fuel and technology qualification, development, and testing resources.
AFC is supported by a large part of the U.S. nuclear complex.

**National Laboratories**
- INL (Idaho National Laboratory)
- Oak Ridge National Laboratory
- Brookhaven National Laboratory
- Argonne National Laboratory
- Los Alamos National Laboratory
- Pacific Northwest National Laboratory

**Universities**
- University of Florida
- University of Illinois
- University of Tennessee
- Texas A&M University
- Georgia Tech
- MIT

**Nuclear Industry**
- GE
- Westinghouse
- AREVA
- Exelon
- TVA
- Southern Company
- EPRI (Electric Power Research Institute)
University R&D plays an important role in advanced nuclear fuels and materials principally through the NEUP program

- Typically > 30 projects in a given year in AFC.
- Large number of lead and collaborating universities.
<table>
<thead>
<tr>
<th>NEUP Project #</th>
<th>Title</th>
<th>PI</th>
<th>Lead Institution</th>
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</thead>
<tbody>
<tr>
<td>16-10668</td>
<td>Microstructure experiments-enabled MARMOT simulations of SiC/SiC-based accident tolerant nuclear fuel system</td>
<td>Jake Eapen</td>
<td>NCSU</td>
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<tr>
<td>16-10221</td>
<td>Alloying agents to stabilize lanthanides against fuel cladding chemical interaction: Tellurium and Antimony studies</td>
<td>Jinsuo Zhang</td>
<td>Ohio State University</td>
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<tr>
<td>16-10667</td>
<td>A coupled experimental and simulation approach to investigate the impact of grain growth, amorphization, and grain subdivision in accident tolerant U3Si2 LWR fuel</td>
<td>Mike Tonks</td>
<td>Pennsylvania State University</td>
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<tr>
<td>16-10648</td>
<td>Microstructure, thermal, and mechanical property relationships in U and U-Zr alloys</td>
<td>Maria Okuniewski</td>
<td>Purdue University</td>
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<tr>
<td>16-10648</td>
<td>Oxidation and corrosion-resistant uranium silicide fuels</td>
<td>Jie Lian</td>
<td>RPI</td>
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<tr>
<td>16-10523</td>
<td>A science based approach for selecting dopants in FCCI-resistant metallic fuel systems</td>
<td>Indrajit Charit</td>
<td>Univ. of Idaho</td>
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<tr>
<td>16-10204</td>
<td>Phase equilibria and thermochemistry of advanced fuels: modeling burnup behavior</td>
<td>Ted Bessmann</td>
<td>Univ. of South Carolina</td>
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2017 ATF Primary Activities

- Year 1 of Phase II ATF Activities
- Initiate ATF-2 loop irradiation in ATR and establish loop irradiation in Halden
- Develop necessary experimental capability for transient testing
- Establish fuel handbooks for ATF technologies
- PIE of initial ATF-1 fuel rodlets
U.S. DOE-supported Industry Teams working to insert ATF into LWR condition loop irradiations

**AREVA**
- Cr coated Zr
- Increased fuel conductivity
- Additives
  - Chromia dopant

**GE**
- Develop advanced ferritic/martensitic steel alloys (e.g., Fe-Cr-Al) for fuel cladding to improve behavior under severe accident scenarios
- Objectives:
  - Characterize candidate steels
  - Study tube fabrication methods, neutronics, fuel economy, thermo-hydraulic calculations, regulatory approval path
  - Initiate ATR testing with UO$_2$ and two cladding materials.

**Westinghouse**
- Cladding concepts:
  - SiC and SiC ceramic matrix composites;
  - coated Zr alloys
- High density/high thermal conductivity fuel pellets
- First batch of U$_3$Si$_2$ pellets were sintered using finely ground powder
- Pellets were pressed using pressures of 6,000-10,000 psi and sintered at temperatures of 1400°C
2017 Advanced Reactor Fuels Activities

- Am distillation
- Np feedstock
- Remote fuel casting
- Advanced fuel fabrication
- Thermal/Fast comparison

KAERI

TerraPower
FY17 Budget

Total FY17 Operating ($56.9M) including FY16 CO
Bilateral International Collaboration
Includes Significant ATF Development

**France**
- Advanced core materials
- Joint support of Halden collaborative irradiations
- Transient Testing

**European Union**
- Three general INERIs currently underway with JRC-ITU

**Japan**
- Definition of attributes and metrics
- Coordination of technology research and development
- Coordination of facilities used for R&D

**China**
- Attributes and metrics
- Information exchange on R&D facilities
- Assessment of ATF Performance
- Collaborative testing opportunities

**UK**
- Active partners in ATF FOAs and IRPs
- Joint participation in ATF OECD/NEA
- Basic material properties of high density fuels

**Others**
- Canada bilateral under development
- OECD/NEA Expert Groups
- IAEA Expert Group on ATF
- Enlarged Halden Reactor Group

**Russian Federation (currently on hold)**
- Advanced LWR fuels and ATF
- Exchange of attributes and metrics
International Collaboration Includes Significant Advanced Reactor Fuels Development

France
- FUTURIX-FTA, MI Irradiation and PIE
- Fuel Performance Code Comparison
- Joint AmBB irradiations in ATR
- Cladding materials
- Trilateral transient testing

Japan
- Metallic fuel
- Oxidation kinetics

China
- Materials and fuels irradiation in CFTR
- Metal fuel fundamental properties

European Union
- Three general INERIs currently underway with JRC-ITU

South Korea (KAERI)
- Metal fuel fabrication technology and irradiation performance through the JFCS

UK – (under development)
- PIE technique development
- Characterization technique development
- Fuel performance modeling and simulation

Russian Federation (currently on hold)
- Materials and fuels irradiation in BOR60
- Characterization and PIE methods
- In-pile instrumentation and testing
- Nitrides

Others
- OECD/NEA, IAEA, GIF-GENIV projects
Summary


- Major Efforts for FY2017
  - Initiating ATF-2 Loop Irradiation
  - Rev 0 of Thermal/Fast Comparison
  - Establish handbooks with revision and update process

- Evolve
Update with new coversheet
Jon Carmack, 10/12/2015
Most documents coming 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

2013 Accomplishments Report
http://www.osti.gov/scitech/servlets/purl/1120800

2014 Accomplishments Report
http://www.osti.gov/scitech/biblio/1169217

2015 Accomplishments Report
http://www.osti.gov/scitech/servlets/purl/1236849

2016 Accomplishments Report
Link in Dec 2016
Thank you
Integrating Industry and DOE Programs: Major Accomplishments and Impact

- **Metallic Fuel**
  - Established remote casting fabrication capability for KAERI CRADA.
  - Established new TerraPower proprietary fabrication line.
  - Irradiating and performing PIE on several TerraPower fuel experiments in ATR accelerating fuel qualification.

- **Accident Tolerant Fuels**
  - Currently irradiating LWR ATF fuel technologies for GE, Westinghouse, and AREVA in ATR.
  - Will initiate (late 2017) the first PWR condition loop irradiation in ATR for ATF vendor fuel technologies.
  - Currently working towards initiating transient testing in TREAT in FY18 to support all technology vendors.
  - Executing PIE on several ATF fuel specimen from ATR ATF-1.
  - Rapidly moving ATF towards 2022 LFA/LFR insertion.

- **TRISO Fuel**
  - Formal fuel qualification underway:
    - AGR-5/6/7 fuel particles and compacts have been fabricated.
    - Majority of AGR-5/6/7 test train components have been fabricated; awaiting fuel compacts to complete fab and load test train.
    - AGR-5/6/7 irradiation scheduled to start at the end of FY17 (194 UCO fuel compacts).
  - PIE on AGR-2 UCO and UO$_2$ fuel is approximately half complete. Confirms excellent performance of UCO fuel and demonstrates increased tendency for SiC degradation in UO$_2$ fuel at elevated temperatures.