U.S. DEPARTMENT OF ENERGY | Nuclear Energy

FC 2: Advanced Fuels

Frank Goldner
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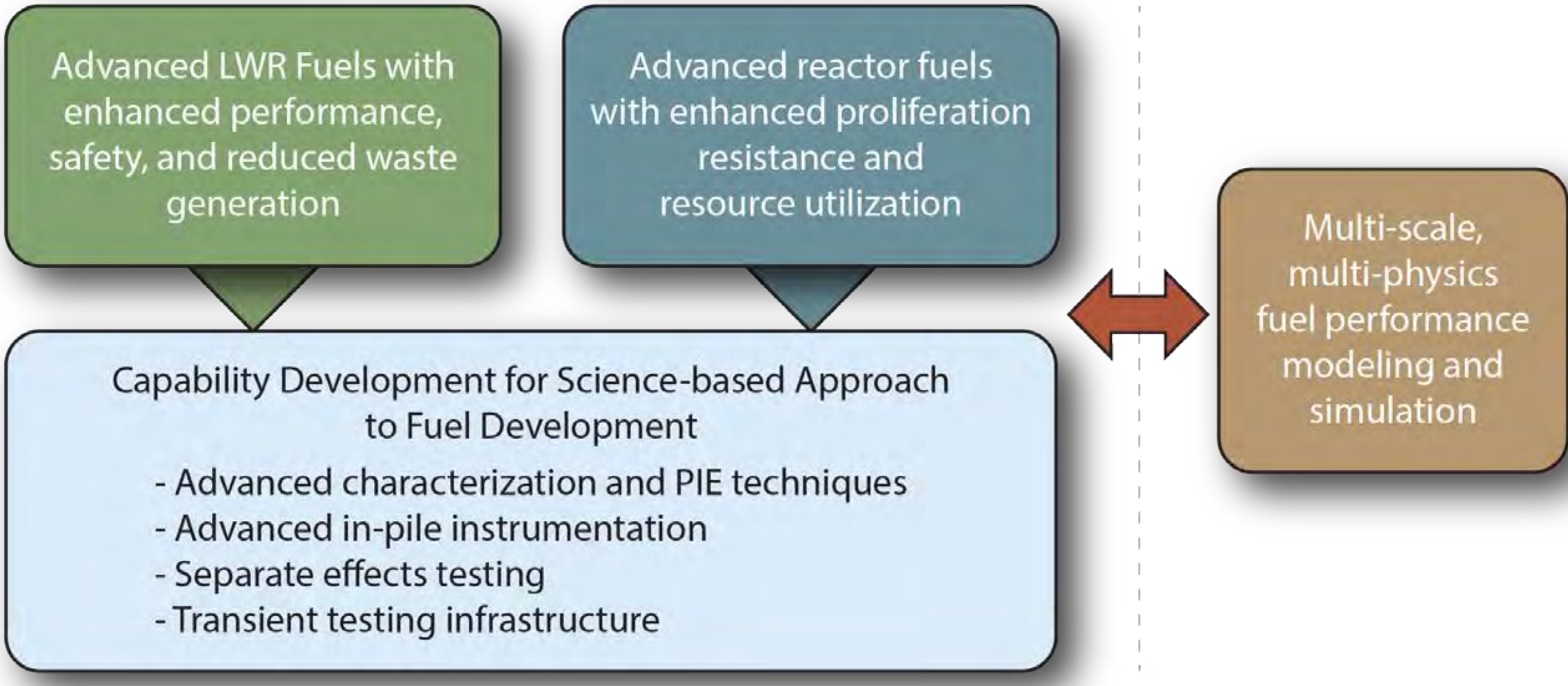
DOE-NEUP FY2018 Webinar
August 8, 2016

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.



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

FY17 NEUP AFC Related Project Awards

NEUP Project #	Title	PI	Lead Institution
17-13011	Gamma-ray Computed and Emission Tomography for Pool-Side Fuel Characterization	Joseph Graham	Missouri Univ. of S&T
17-13131	Nanostructured Composite Alloys for Extreme Environments	Osman Anderoglu	University of New Mexico
17-12463	Extreme Performance High Entropy Alloys (HEAs) Cladding for Fast Reactor Applications	Adrien Couet	University of Wisconsin-Madison
17-12609	Development of Advanced High-Cr Ferritic/Martensitic Steels	Kester Clark	Colorado School of Mines
17-12549	Critical Heat Flux Studies for Innovative Accident Tolerant Fuel Cladding Surfaces	Michael Corradini	University of Wisconsin-Madison
17-12688	An Experimental and Analytical Investigation into Critical Heat Flux (CHF) Implications for Accident Tolerant Fuel (ATF) Concepts	Youho Lee	University of New Mexico
17-13019	Evaluation of Accident Tolerant Fuels Surface Characteristics in Critical Heat Flux Performance	Sama Bilbao y Leon	Virginia Commonwealth University
17-12647	Determination of Critical Heat Flux and Leidenfrost Temperature on Candidate Accident Tolerant Fuel Materials	Matteo Bucci	Massachusetts Institute of Technology

FC 2.1 – Benchmarking Microscale Mechanical Property Measurements

Federal Manager: Janelle Eddins

Technical POC: Stuart Maloy (LANL)

- **Recent research has shown the benefits of microscale mechanical testing and has significantly advanced the field for nuclear materials. However, more research is needed to correlate microscale measurements to the macroscale (particularly for ductility measurements). Techniques including micro tensile, micro compression, micro bending and nano hardness have been developed and have demonstrated that mechanical properties can be evaluated on nm and µm length scales. These techniques have extensive applications as they enable the nuclear materials community to generate mechanical property data even on heavy ion beam irradiated materials as well as on radioactive materials. With the excellent progress made on developing these microscale techniques, more research is needed to standardize these practices and benchmark the results against those from macroscale measurements. Issues including effects of artefacts from preparation, scale of the microstructure, multiphase materials, microscale segregation, and local texture on results need to be studied. Thus, proposals are sought on correlating microscale mechanical testing data with macroscale data for testing of irradiated nuclear materials for high dose applications. In addition, there has been very little development of microscale ductility measurement techniques which is particularly important for some of the more advanced alloys. Hence, priority will be given to proposals that include a method for microscale ductility measurement and comparison to macroscale mea**

Applying Microscale Property Measurements to the Macroscale

- **Current microscale measurement techniques demonstrate that mechanical properties can be evaluated on nm and µm length scales**
  - Especially useful for evaluating ion beam irradiated material where damage depth is 1-10 microns

- **Techniques developed include: micro tensile, micro compression, micro bending and nano hardness**
  - Very little development of ductility measurement techniques

- **Proposals are sought to benchmark microscale techniques against macroscale techniques and to investigate how microscale data applies to bulk material properties**

- **Priority given to applications which investigate and benchmark ductility measurement techniques**

FC 2.2 – Advanced Fabrication Methods for Metallic Fast Reactor Fuels

Federal Manager: Janelle Eddins

Technical POC: Steve Hayes (INL)

- **The Advanced Fuels Campaign is currently investigating advanced casting and extrusion processes for the fabrication of metallic transmutation fuels. Proposals are sought for novel fabrication methods for metallic fast reactor fuels having the potential for economic, fuel performance, or manufacturability improvements over existing fabrication techniques for future commercial applications. Fabrication methods having the potential to meet the 0.1% loss goal for the metallic fast reactor fuel systems currently under study by the Advanced Fuel Campaign are also desired for future commercial applications.**

Advanced Fabrication Methods for Metallic Fast Reactor Fuels

- **Current Program Focus:**
  - Fabrication techniques for transmutation fuels that minimize process loses
  - Reducing process losses to <0.1% irrecoverable loss of actinide material
  - Extensibility to remote fabrication is desirable
  - Development of coatings, liners, etc., to mitigate fuel-cladding chemical interaction
  - Advanced fabrication techniques for metallic fuels such as extrusion and continuous casting
  - Improvements on historical casting methods
    - *Robust/reusable molds and crucible materials*
    - *Rapid cycle times and casting under pressure to minimize volatile losses*
    - *Downpour/gravity casting methods vs. counter-gravity injection casting to improve melt utilization*
- **Proposals are sought for novel fabrication methods for future commercial applications which result in improved economics, fuel performance, and/or manufacturability as compared to existing techniques**
- **Fabrication methods and improvements having the potential to meet the 0.1% loss goal for future commercial applications are highly desired**
- **Only concepts applicable to metallic fuel fabrication will be considered**
- **Use of appropriate surrogate materials in place of actinides is acceptable**

FC 2.3 – Damage and Failure Mechanisms for SiC/SiC Composite Fuel Cladding and Mitigation Technologies

Federal Manager: Frank Goldner

TPOC: Yutai Katoh (ORNL)

- **Failure of SiC/SiC composite fuel cladding occurs under a complex operating environment involving hydrothermal corrosion, radiolysis, radiation damage, and mechanical loading. Proposals are solicited for fundamental to applied research and development in one or more of the following areas:**
  - 1) Multi-axial failure criteria for SiC/SiC composites: complex stress states develop in SiC/SiC composites during services in nuclear systems. While the design criteria and test methods have been reasonably established for uniaxial or simple hoop loading to the ceramic matrix composite test articles, insufficient work has been done for multi-axial failure and testing, limiting ability of code-qualification for CMC components. Establishing the multi-axial failure criteria and development of appropriate test methods to support the experimental investigation and validations of nuclear-grade SiC/SiC composites is required;
  - 2) Understanding radiolytically assisted hydrothermal corrosion of SiC: dissolution of SiC in operating environments combining oxidative water chemistries and water radiolysis is a critical feasibility issue for SiC-based fuel and core components in LWRs. While various mitigation strategies are actively studied, it is important to establish scientific understanding of the detailed corrosion kinetics of the radiolytically assisted hydrothermal corrosion of SiC and the factors that determine the rate of corrosion. Goal of the solicited project is to enable mapping of SiC corrosion rate in the water chemistry – radiolysis intensity – temperature space. A technical approach combining experiments and computational modeling is highly encouraged;
  - 3) Corrosion barrier technologies for SiC/SiC composites: for widespread applications of SiC-based materials in water reactor systems, environmental barrier coating technologies or novel matrix/surface modification technologies that provide protection against radiolytically assisted hydrothermal corrosion in LWR normal chemistry water need to be developed. This call solicits research toward development of such technologies. Technical approaches are encouraged that recognize the existing state-of-the-art, and are scalable to industrial production of full length fuel rods, and possibly other core components, such as to inside coating/modification of LWR channel boxes.

Damage and Failure Mechanisms for SiC/SiC Composite Fuel Cladding and Mitigation Technologies

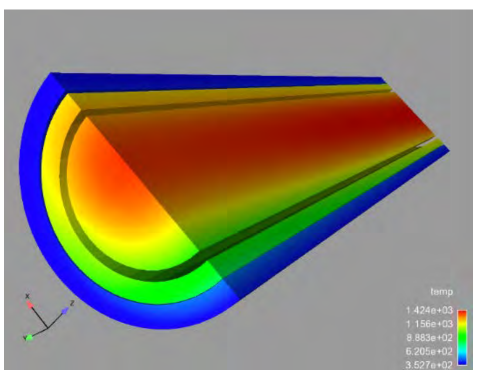
- **Current Program Focus:**
  - Accident Tolerant Fuel development with potential commercial utilization in the mid 2020 time period
  - Utilization of the existing national lab development and testing capabilities to support needs of proposed accident tolerant candidate concepts prioritized by the industry
  - Consideration of design basis and beyond design basis licensing related development needs, and associated testing to provide input and support model development

- **Proposals are sought to advance the state-of-the-art in understanding, analyzing, and mitigating failure mechanisms of SiC/SiC composite LWR oriented fuel cladding under complex operating environments involving hydrothermal corrosion, radiolysis, radiation damage, and mechanical loading in one or more of the following areas:**
  - Multi-axial failure criteria for SiC/SiC composites
  - Understanding radiolytically assisted hydrothermal corrosion of SiC
  - Corrosion barrier technologies for SiC/SiC composites

- **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.**

Key Items to Consider

- **Must show relationship to elements of the Advanced Fuels Program**
  - Priority given to proposals that support LWR accident tolerant fuel and fast reactor fuel concepts under study by FCRD
- **Review previous NEUPs to avoid duplication of activities**
- **Include reasonable timelines and deliverables**
- **Proposals tying experimental activities with modeling, where applicable, will be given higher priority**
  - Should support codes and models being developed by FCRD and NEAMS



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Contact Information

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- **Please review previous fuel related awards on www.neup.gov.**

AFC Advanced Fuels Campaign

NEUP Nuclear Energy University Programs

U.S. Department of Energy

Background Information

Advanced Reactor Fuels Development

- **Scope:** Advance the scientific understanding and engineering application of fuels for use in future fast-spectrum reactors; includes: 1) support for driver/startup fuel concepts, and 2) fuels for enhanced resource utilization (including actinide transmutation).

- **Domestic R&D focused on metallic fuel containing minor actinides**

- **Metallic Fuels Technology**
  - Fuel Fabrication/Fabrication Development
  - Fuel Optimization/Characterization
  - Fuel Feedstock Preparation
  - Cladding/Core Materials Development
  - Irradiation Testing and Post-irradiation Examinations
  - Fuel Modeling Support

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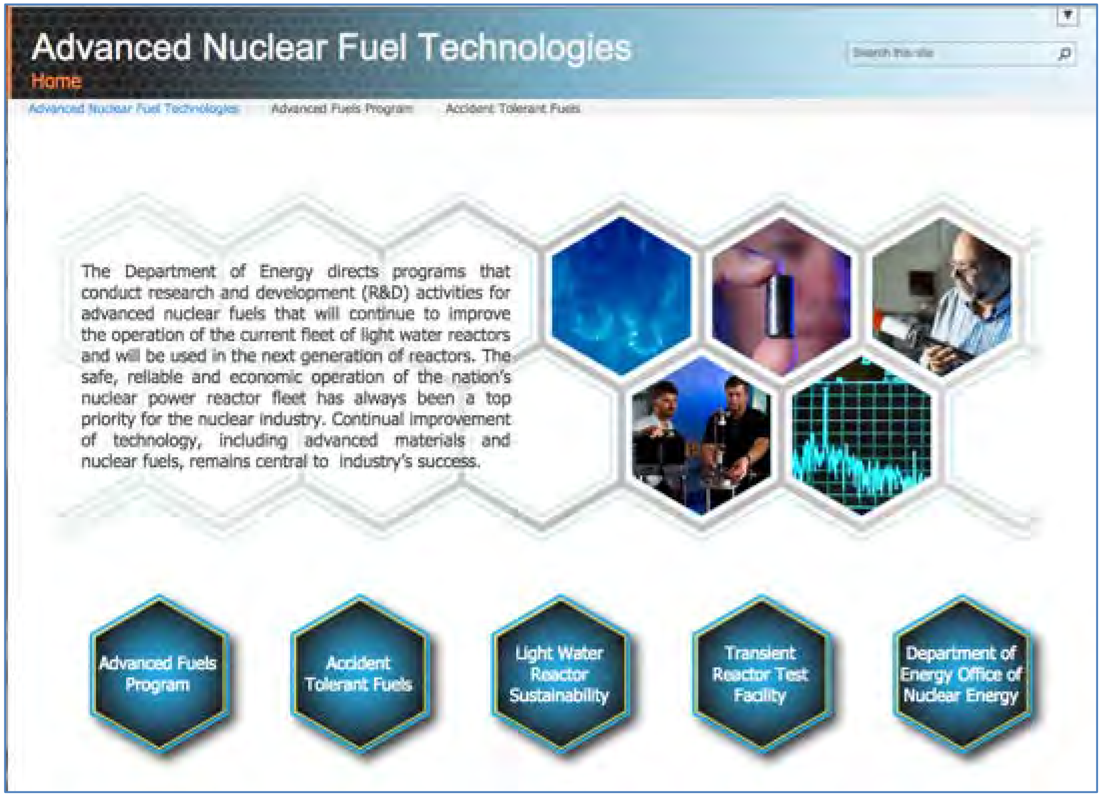
Advanced Fuels Website
https://nuclearfuel.inl.gov



Accident Tolerant LWR Fuel Information Sheet

Advanced Fuels Campaign

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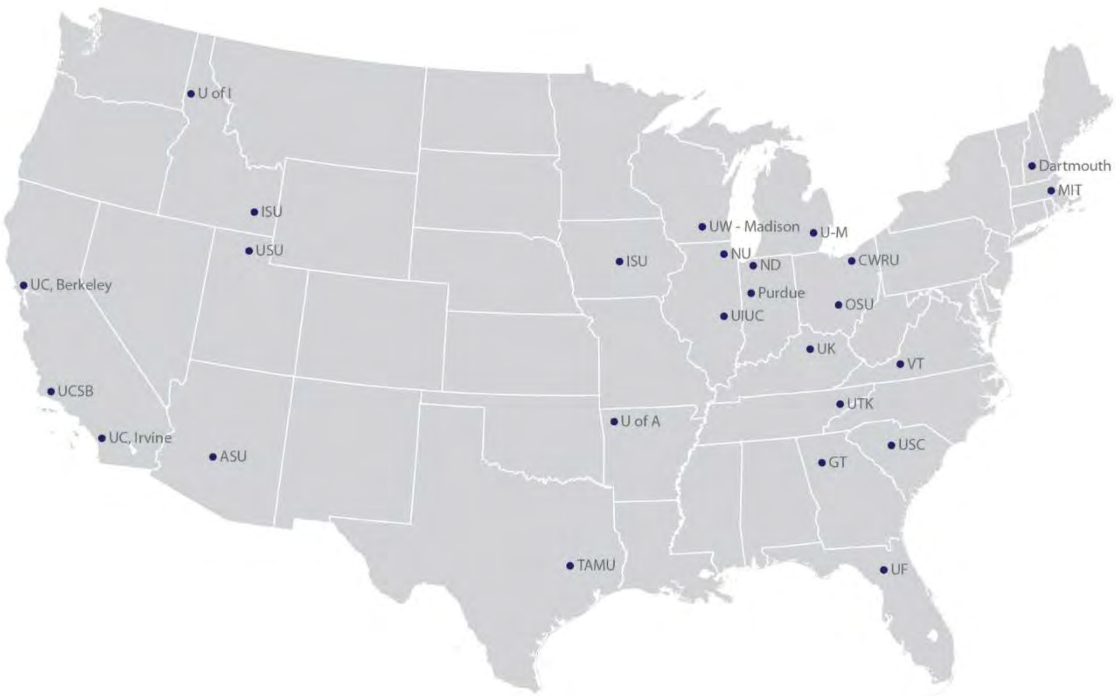
University R&D plays an important role in advanced nuclear fuels and materials principally through the NEUP program

- **Typically > 30 projects in a given year in AFC**
  - 7 awarded in FY2016
- **Large number of lead and collaborating universities**



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Recent Advanced Fuels Campaign Documents – Available on OSTI

OSTI Document Links of Interest:

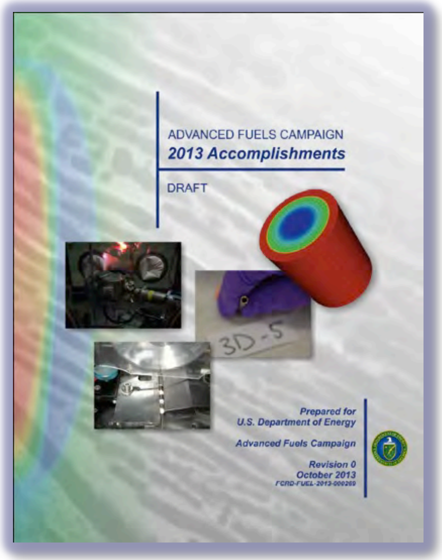
Overview of Accident Tolerant Fuel Program
http://www.osti.gov/scitech/servlets/purl/1130553

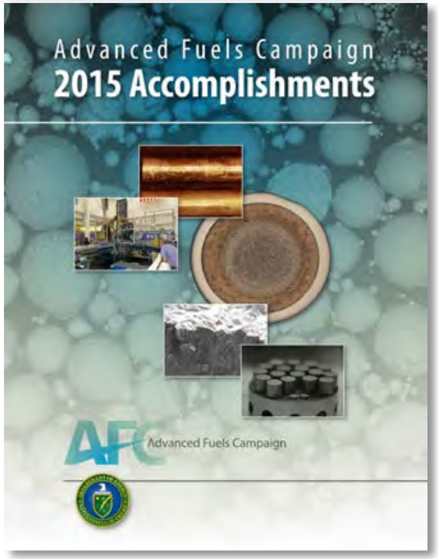
Accident Tolerant Fuel Performance Metrics
http://www.osti.gov/scitech/servlets/purl/1129113

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





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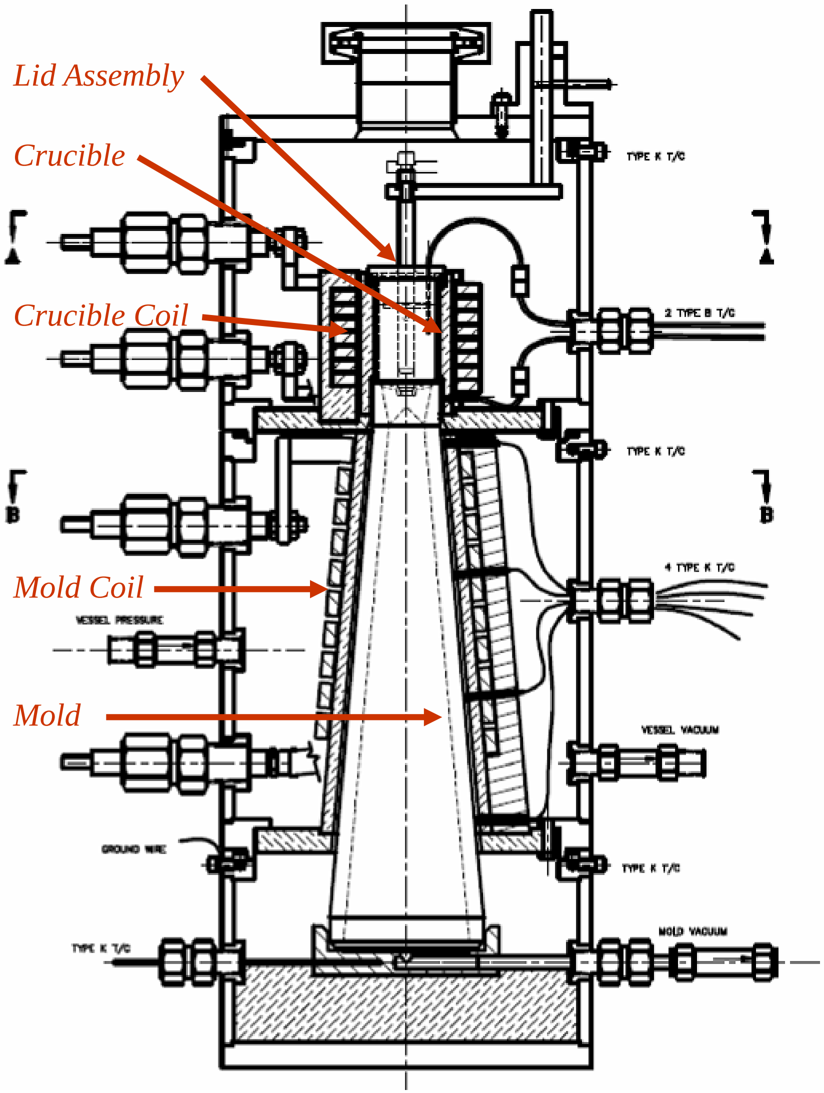
Development of New Casting Process



- **Rapid cycle time, advanced crucible and mold materials**
  - Minimize fuel losses to coatings and single-use molds
  - Minimize high level wastes
  - Eliminate crucible cleaning and coating
  - Minimize contamination or reaction of melt
- **Bottom casting process**
  - Increase charge utilization (up to 100%) and throughput
  - Eliminate volatile loss mechanism
    - *Melt pool covered*
    - *Not exposed to vacuum*
- **Casting under pressure**

1) Greatly improved melt utilization, and
2) Near-zero Am loss during fabrication.

SiC/SiC Related Reference

ORNL/TM-2017/385

SiC/SiC Cladding Materials Properties Handbook

Nuclear Technology Research and Development

Prepared for
U.S. Department of Energy
Nuclear Technology Research and Development Advanced Fuels Campaign

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August 2017
M3-FT17OR020202104