U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy Enabling Technologies (NEET)

Advanced Sensors and Instrumentation (ASI) Annual Project Review

High Temperature Fission Chamber (HTFC)

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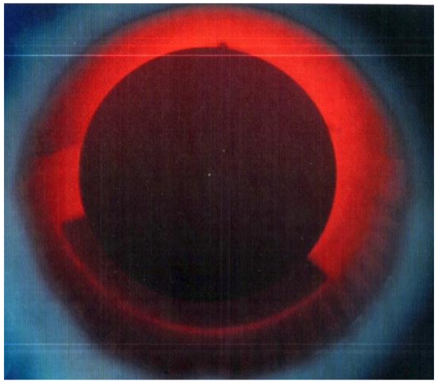
Project Overview

Goals and Objectives

- Design, fabricate, and test a prototype HTFC
- High sensitivity (1 cps/nv), 2 year life, operation in FLiBe or He at 800 °C



ORNL prototype chamber (prior work) in furnace in air at ~600 °C

DOE-R&D programs benefitting from this work

- High Temperature Gas Reactor (HTGR)
- Fluoride Salt Cooled High-Temperature Reactor (FHR)
- Advanced Small Modular Reactors (Advanced SMR)
- Lead Fast Reactor

Project Overview

Participants

- ORNL
  - Z. W. Bell (PI) – Sanity checks, MCNP/SRIM calculations, measurements
  - R. J. B. Warmack – Materials, gas, prototype construction
  - R. G. Miller – brazing/joining/welding
  - M. J. Lance – insulators
  - B. Jolly – metals (Ni, Ni alloys)
  - D. Wilson – environmental effects on structural materials
  - R. T. Mayes – U plating
  - M. J. Harrison – MCNP/SRIM calculations, measurements
  - D. Giuliano – mechanical and thermal engineering
  - C. L. Britton – electronics
- Ohio State University
  - Thomas Blue – research reactor irradiation
  - Lei Cao – research reactor irradiation

Technology Impact

- **Project is focused on performing the RD&D necessary to resolve the current technical issue of lack of high-sensitivity, high-temperature neutron flux monitoring technology**
- **Impact on other DOE-NE programs**
  - This project provides an enabling technology for DOE-NE's high-temperature reactor development programs (Roadmap R&D Objective 2)
  - SMRs are contemplated to use liquid salt or flowing He coolant: This project addresses problems related to survival of instrumentation in these environments
  - NEAMS – Enables validation of models through experiments and measurements

Research Plan

- **FY2012 - HTFC candidate component selection ($350k)**
  - Evaluated material and component requirements against actual properties
  - Issued report ORNL/LTR-2012/331 " Materials Selection for a High-Temperature Fission Chamber" (available on PICS:NE)
- **FY2013 - Preliminary design ($264k)**
  - Conducting validation experiments based on FY2012 work
  - Preliminary design scheduled for completion near end of FY2013

Research Plan

- **FY2014 - Preliminary design testing ($389k)**
  - Fabricate ^{nat}U chamber
  - Laboratory testing at room temperature (RT) with thermal neutron source
- **FY2015 - LEU chamber design and initial fabrication ($305k)**
  - Finalize dimensions and materials
  - Perform plating with LEU
  - Issue final design specifications
- **FY2016 - LEU chamber fabrication and testing ($624k)**
  - Design tests to be performed at HFIR and OSU (test protocol, fixturing, arranging disposition/salvage)
  - Fabricate 2 LEU chambers
    - Test in laboratory and at HFIR
    - Test in dry tube at Ohio State University at 800 °C
  - Issue reports on characterization of performance

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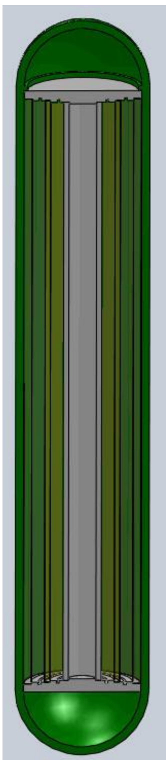
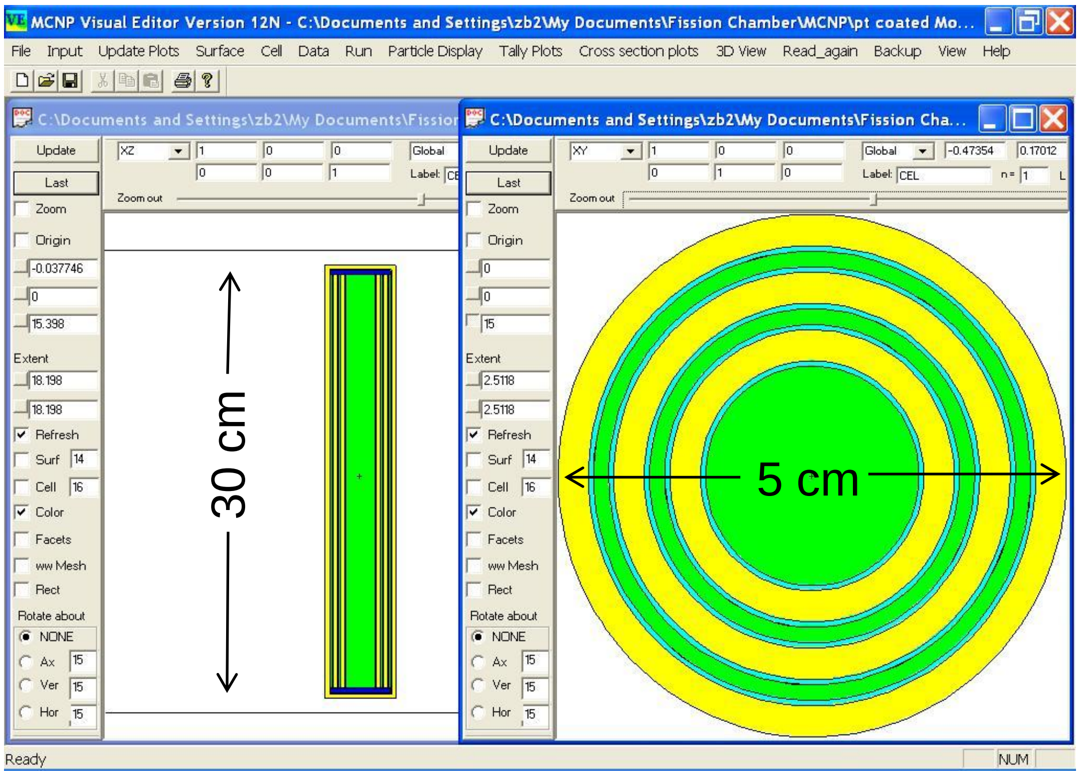
FY2012 Accomplishments: Materials, Shapes, Sizes

Basic design

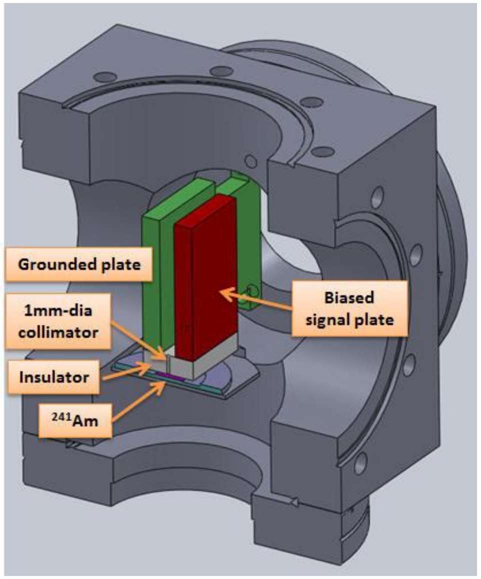


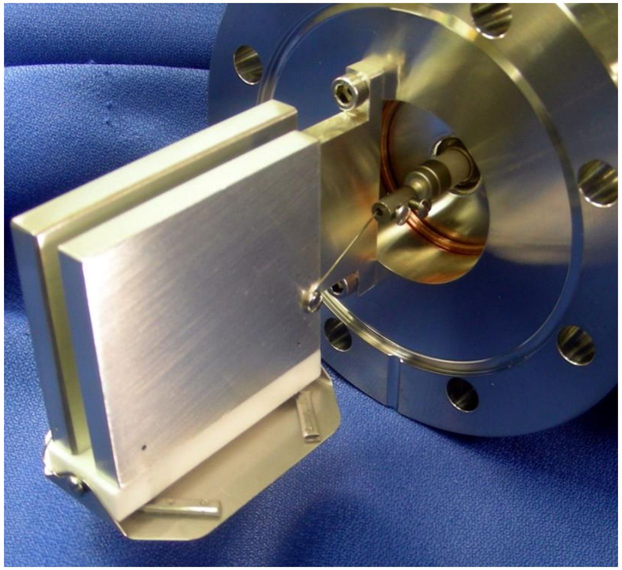


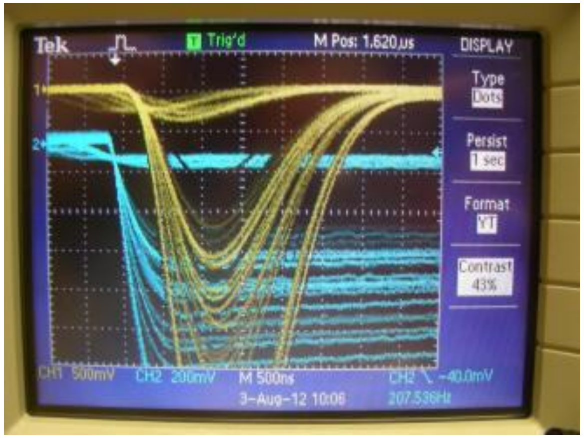
- Alumina shells (2-3 mm), plated electrodes, Ar/Kr/Xe+N_2 gas, 1-2 bar He for heat transport, Ni/Ni alloy flashing outer layer for protection

FY2012 Accomplishments

- **Parallel plate test chamber tells us about expected pulse shapes**

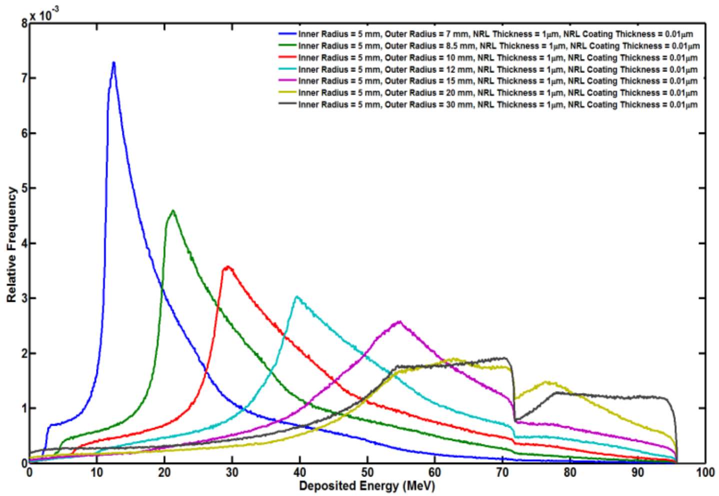




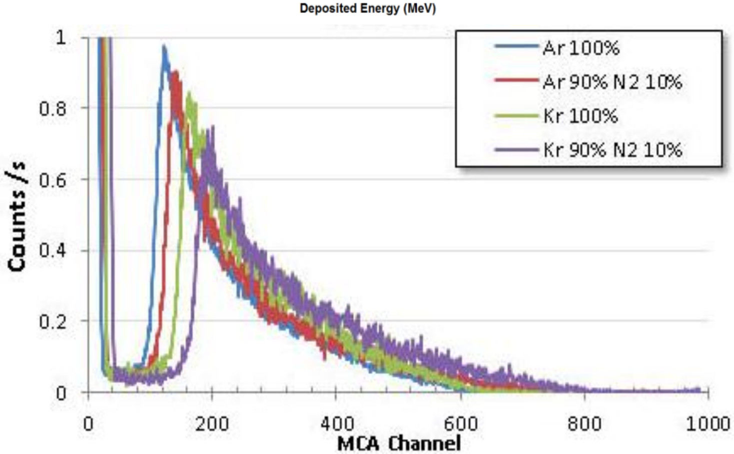


FY2012 Accomplishments

■ MCNP/SRIM modeling



Modeling provides estimated distribution of energy deposition



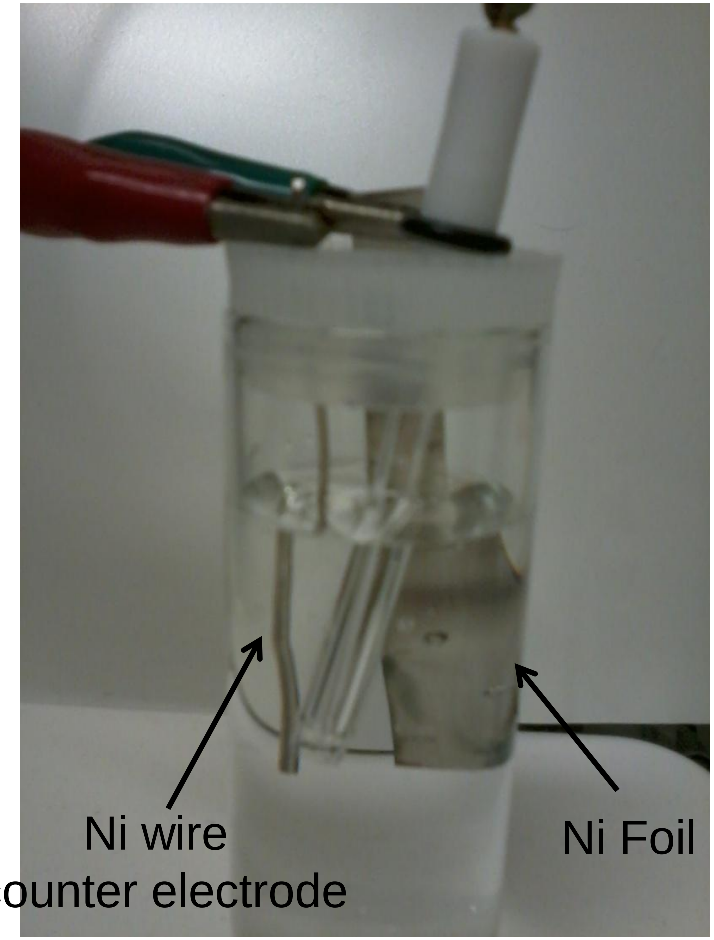
Experiments validate charged particle transport model

FY2013 Activities

- **FY2013**
  - Develop preliminary construction specifications
  - Conduct validation experiments
    - Brazing
      - Test brazes with operating temperatures up to 1000 °C
      - Test pre-coating alumina surfaces
    - FLiBe
      - Compatibility with Ni/Ni alloys
      - Leaches alloying metals from Ni alloys (mostly Cr)
    - Nitriding U platings on Ni

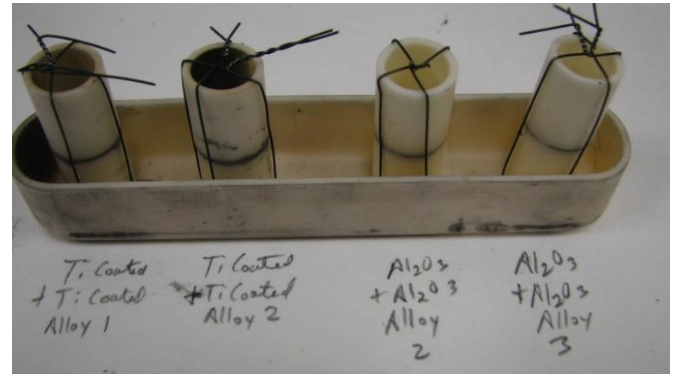
FY2013 Accomplishments

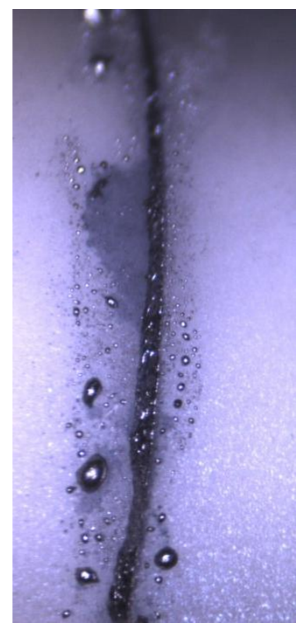
- **Aqueous DU electroplating**
  - Chemically equivalent to EU plating
  - Puts down UO_2 layer
  - Exposure to 30% NH_3:N_2 to convert UO_2 to UN
  - Prefer UN because no phase changes
  - Have observed degradation of Ni surface after annealing
    - Porosity, generally along grain boundaries
    - Ni film remains rigid, but more brittle
    - Not expected to be a problem in the chamber because we are not flexing the film electrode

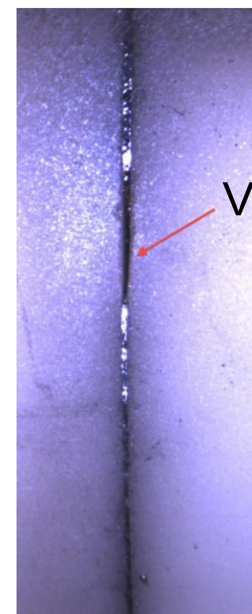


FY2013 Accomplishments

- **Brazing alumina**
  - Pd/Ni braze powder with organic braze cement
  - Some samples pre-coated with Ti
  - Better results with Ti pre-coating







Planned Accomplishments

- **FY2014**
  - Construct and test ^{nat}U chamber
- **FY2015**
  - Develop final construction specifications from FY2014 test data
  - Perform and characterize LEU plating
- **FY2016**
  - RT Laboratory and HFIR testing of LEU chamber
  - Issue construction specifications
  - Issue final report on construction and characterization of HTFC

Crosscutting Benefits

- **DOE-R&D programs benefitting from the research**
  - HTGR
  - Fluoride Salt Cooled High-Temperature Reactor
  - Advanced SMR
  - Lead Fast Reactor
- **Tangible benefits**
  - HTFC will become part of the normal instrumentation architecture for high temperature reactors.
  - Materials evaluation for compatibility with molten salt at 800 °C
- **Validation and coordination**
  - Have discussed the HTFC with HTGR and FHR reactor designers, NGNP technical director
  - Detailed coordination is not required until functional devices have been developed

Crosscutting Benefits

- **Outcomes**
  - Development and documentation of the technology necessary for high-temperature fission chambers (up to 800 °C operation)
  - Demonstration of an operational HTFC
- **Measure of success**
  - Principal measure of success is whether this technology is employed in the next generation of high temperature reactors

Transition to Competitive Research

- **Clear necessity for the research**
  - High-temperature flux monitoring is an acknowledged need for high-temperature reactors
  - Flux at startup & core dynamics measurements are necessary for safe operation of high-temperature reactors
  - There is **NO** HTFC in the market today operational at 800 °C
- **DOE-NE has already invested two years in HTFC design**
- **Path to competitive research**
  - Fabrication with ^{nat}U is the logical next step to prove the design in the lab
  - Fabrication with LEU followed by characterization at high temperature in a reactor
    - Demonstrates sensitivity
    - Demonstrates mechanical/thermal robustness
    - Enables path to safe high-temperature reactors

Conclusion

- We support R&D Objective 2: affordable new reactors
- HT reactors will require instrumentation to cover startup to full power
- Monitoring the reactor flux is a basic safety and control function for nuclear power plants and ensuring the preservation of this capability as high-temperature reactors are introduced into the market directly benefits the nuclear industry. Several of the GenIV reactors have temperatures above those possible for existing fission chambers. This project will enable high temperature reactors to follow the proven safety and operational path of light water reactors.