U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Office Of Nuclear Energy Sensors and Instrumentation Annual Review Meeting

Enhanced Micro-Pocket Fission Detector (MPFD) for High Temperature Reactors

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Idaho National Laboratory
Nuclear Energy Enabling Technologies

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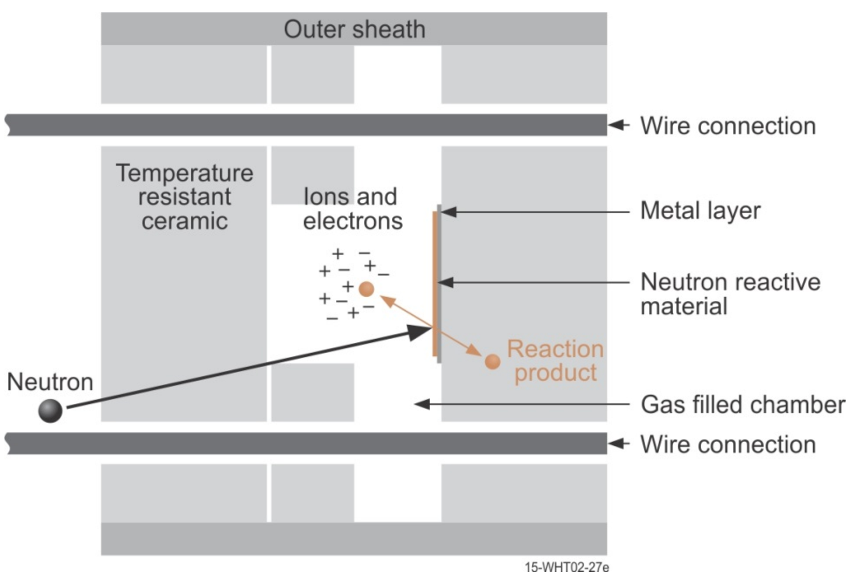
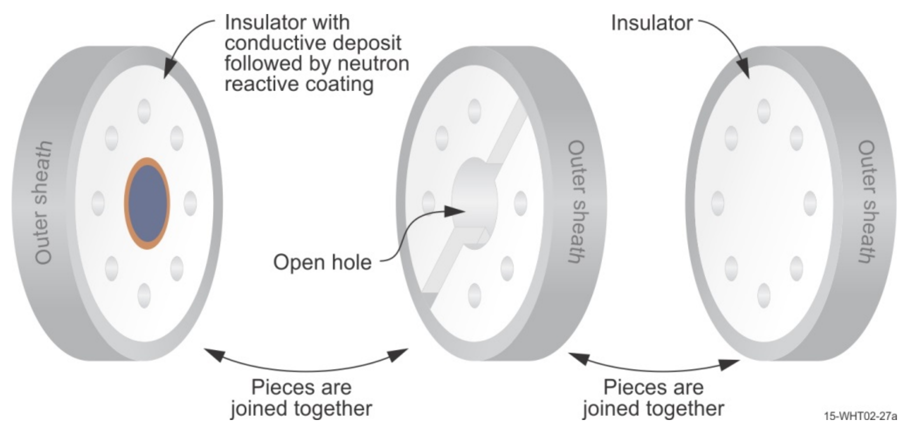
Project Overview

Goal, and Objectives

- Develop and test high temperature capable (to 800 ºC) Micro-Pocket Fission Detectors (HT MPFDs), which are compact fission chambers capable of simultaneously measuring thermal neutron flux, fast neutron flux and temperature within a single package.



Micro-Pocket Fission Detector Theory of Operation

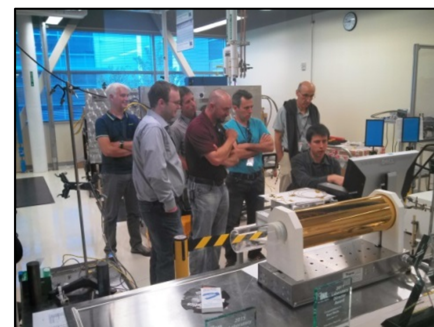


Micro-Pocket Fission Detector Diagram

Project Overview

NEET Participants

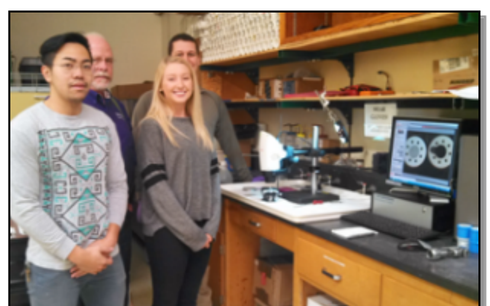
- Troy Unruh and HTTL Staff; Idaho National Laboratory
- Douglas McGregor, Michael Reichenberger and Sarah Stevenson and SMARTLab Staff; Kansas State University
- Jean-François Villard and CEA Instrumentation Staff; Commissariate a l'energie atomique



NEET
Nuclear Energy Enabling Technologies

K-STATE
Kansas State University

INL
Idaho National Laboratory



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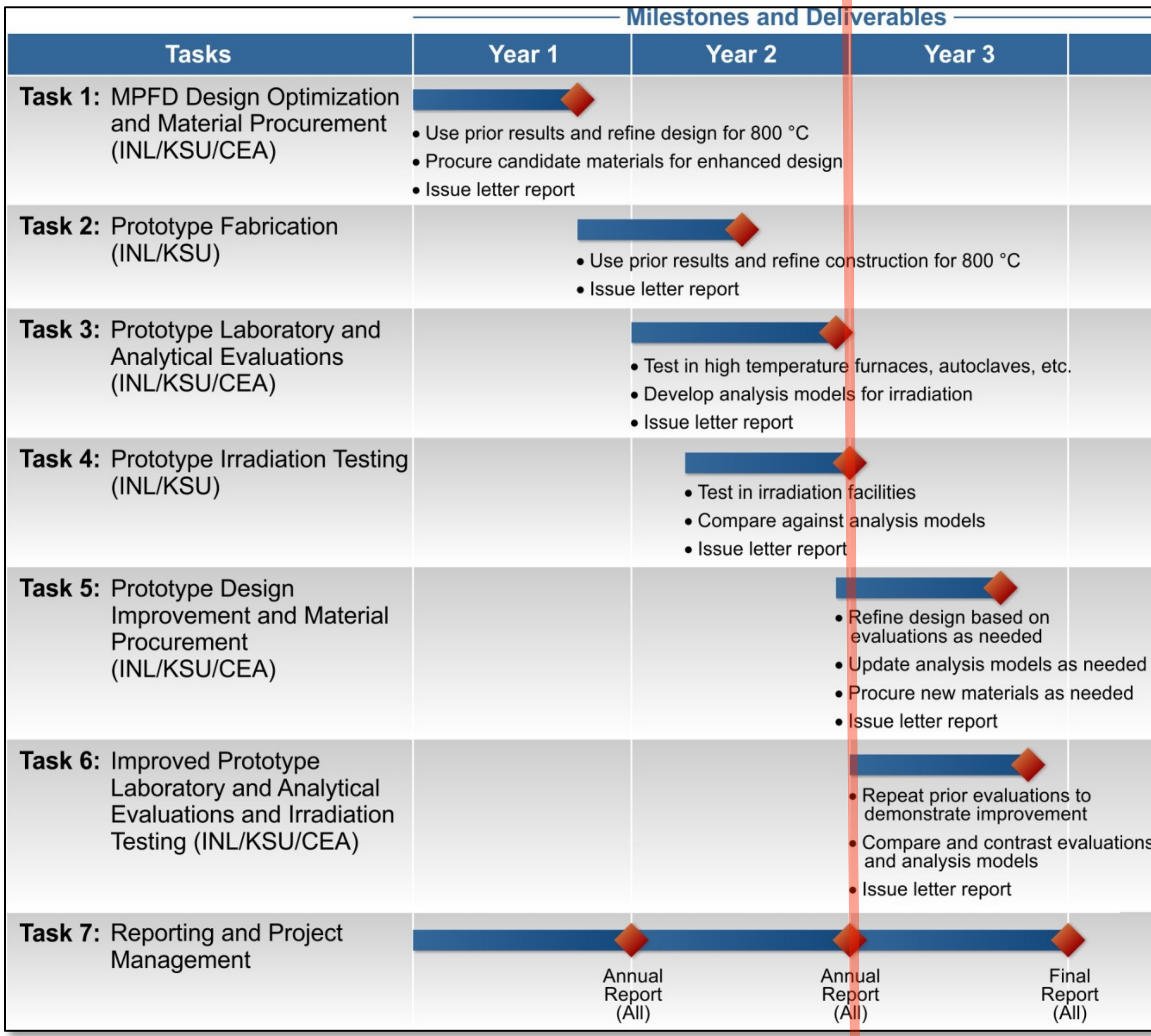
Project Overview

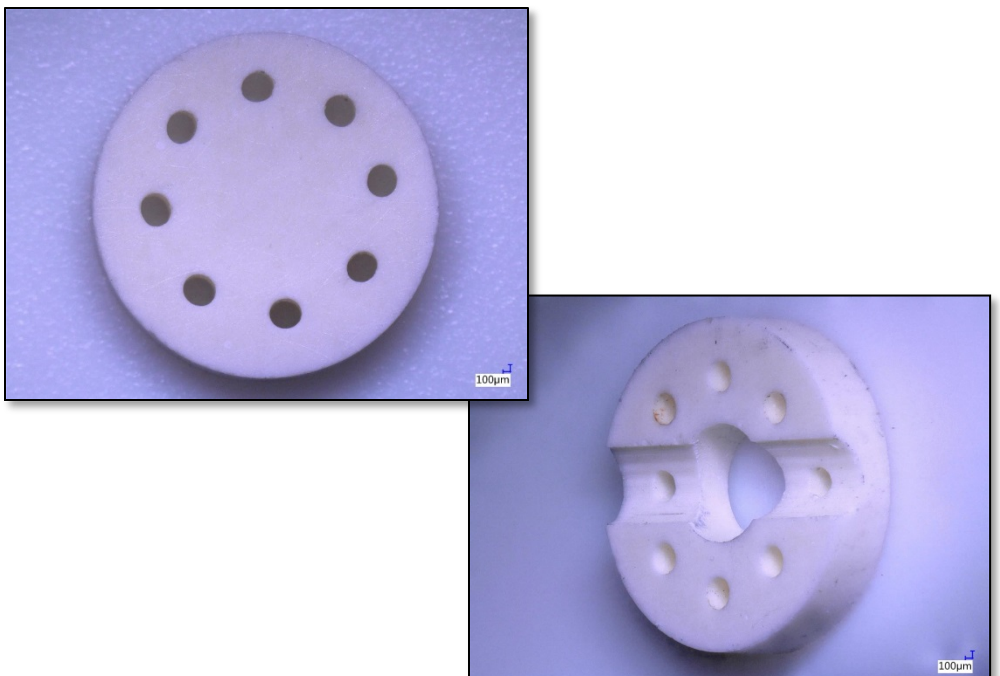
- **Schedule**



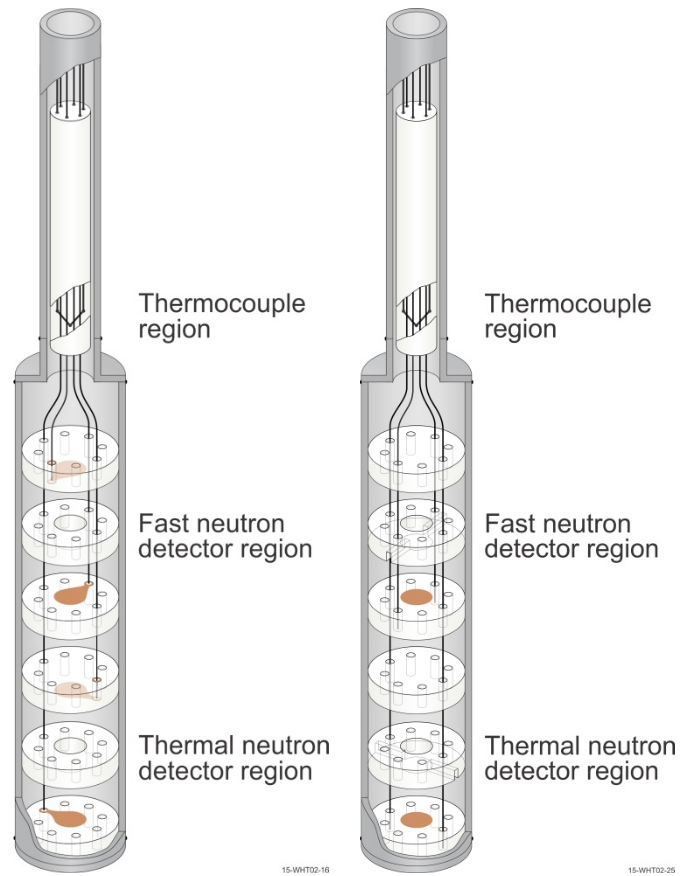
Accomplishments

FY16 Milestones, Deliverables and Outcomes

- Design improvements
  - Parallel plate to parallel wire design
  - Smooth and machined alumina



Smooth MPFD alumina (left) and machined alumina (right)

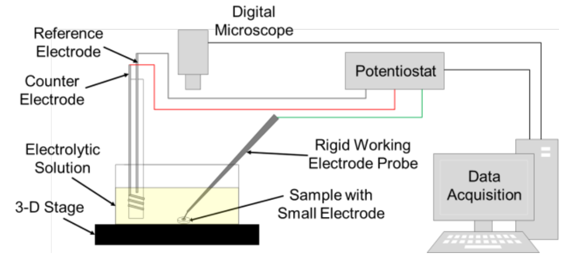


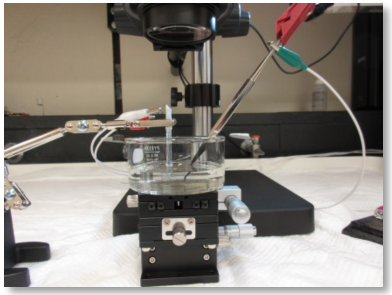
Parallel plate design (left) and parallel wire design (right)

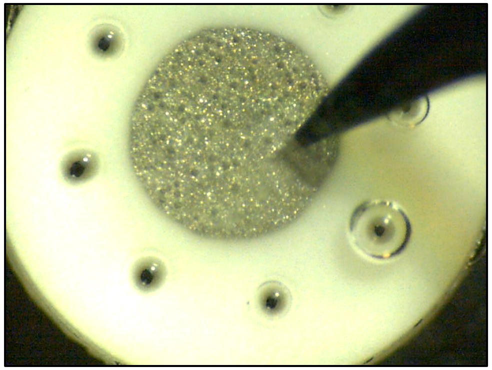
Accomplishments

FY16 Milestones, Deliverables and Outcomes

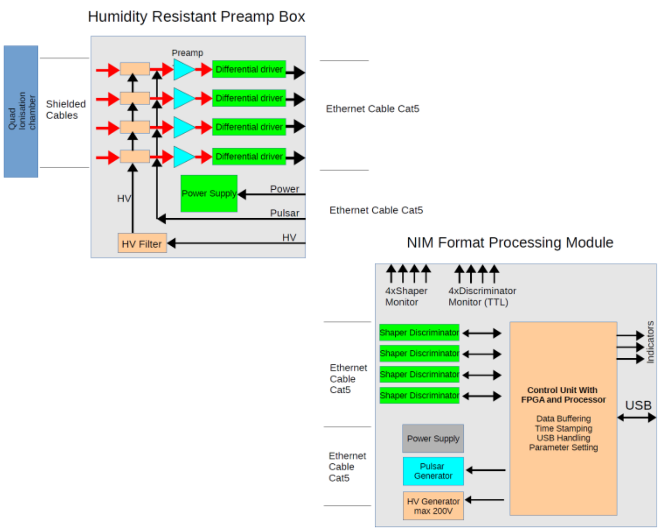
- Received HT MPFD components from KSU for assembly (M3), 3/31/2016
- Revise electroplating and amplifier development at KSU (M4), 8/12/2016



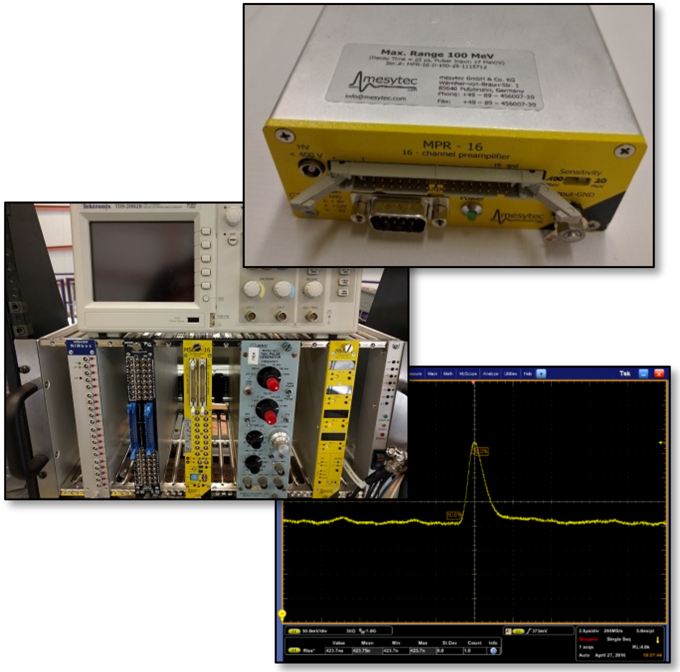




MPFD electrodeposition equipment



MPFD electronics layout

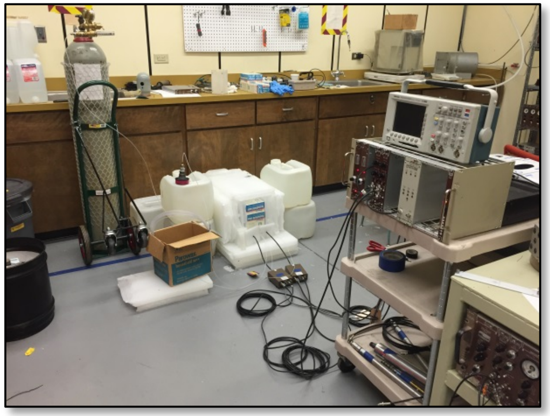


MPFD electronics testing

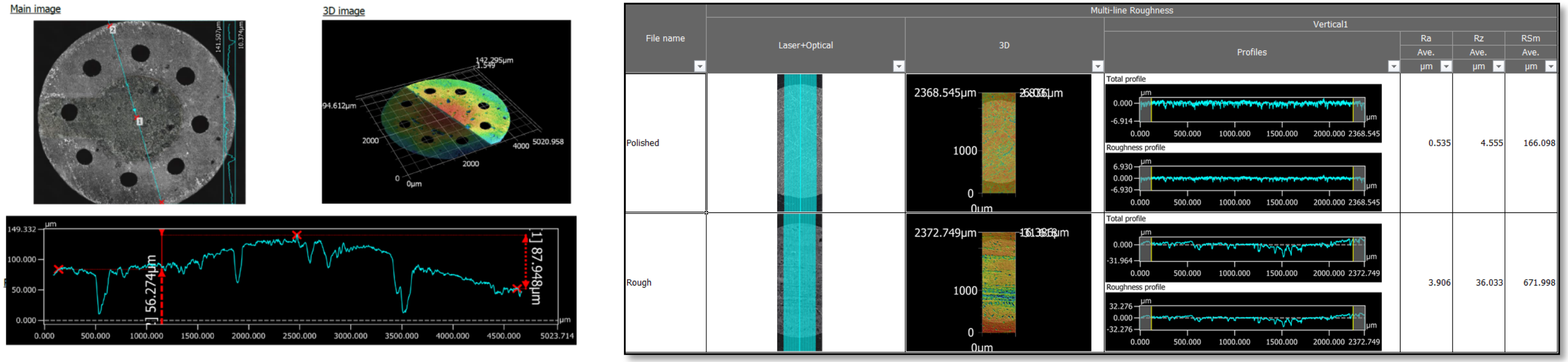
Accomplishments

FY16 Milestones, Deliverables and Outcomes

- Fission material characterizations underway
  - Idaho State University (ISU) MS student (funded by TREAT IRP)
    - Alpha counting
    - Back-to-back fission chamber comparisons
    - 3D confocal laser scanner
    - ISU reactor measurements



MPFD fissile deposit characterization in ISU laboratory

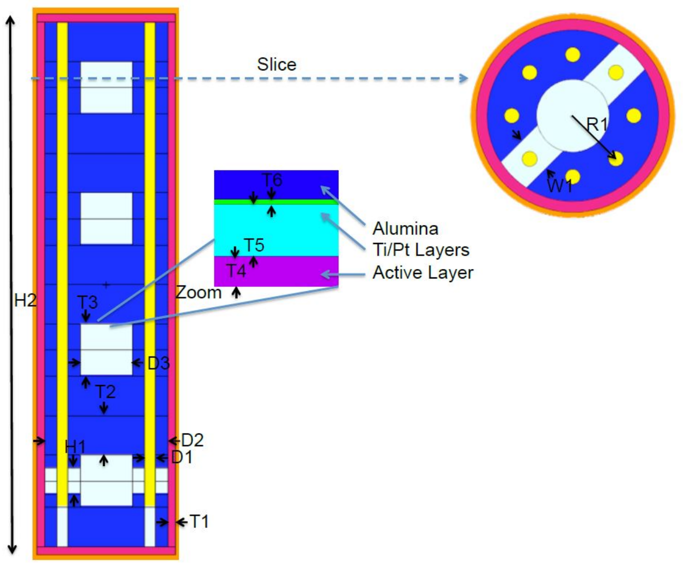


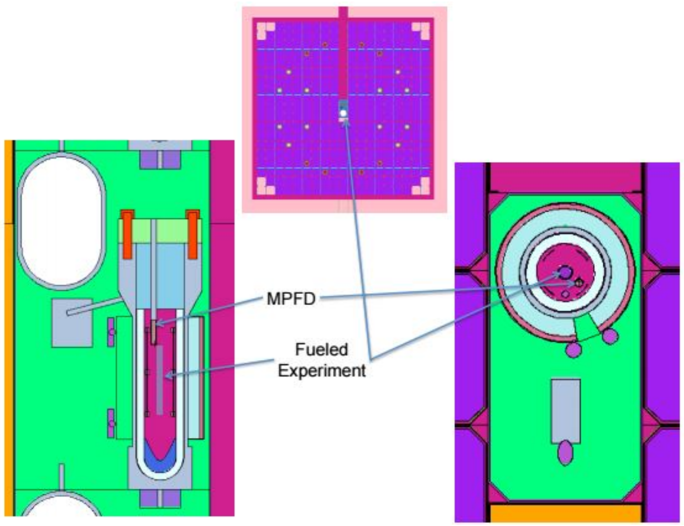
3D laser scans of MPFD (non-fissile) surface roughness

Accomplishments

FY16 Milestones, Deliverables and Outcomes

- MCNP model developed for ATF-3 deployment (ATF-3 funded)
  - Explicitly model MPFD response
  - Determine optimal MPFD location in test



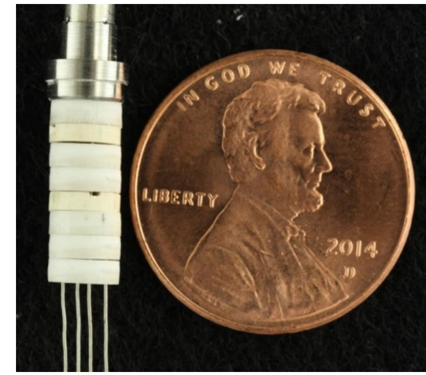


MCNP Transient MPFD model (left) and location in experiment (right)

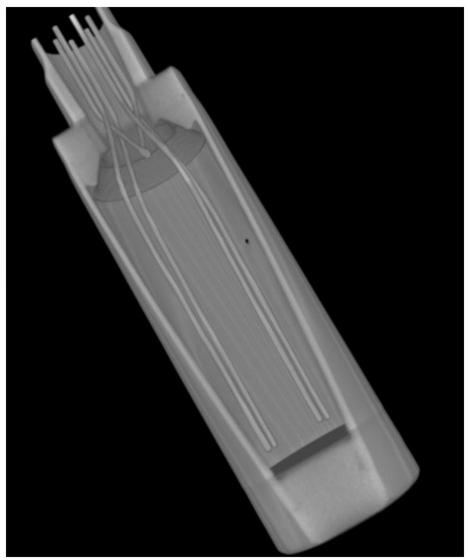
Accomplishments

FY16 Milestones, Deliverables and Outcomes

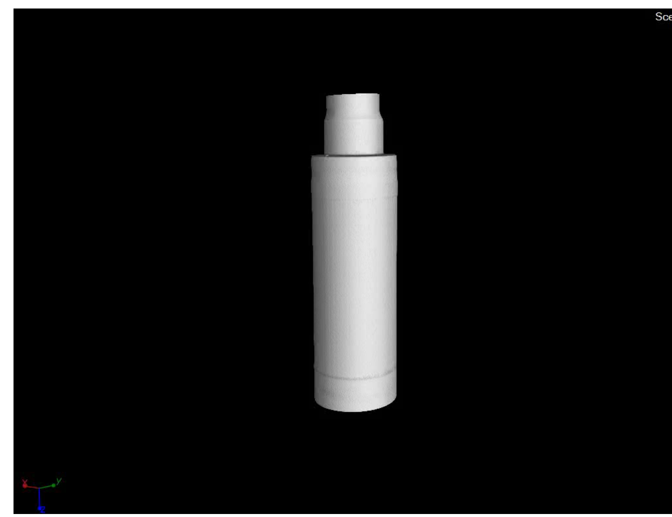
- Assembled HT MPFD at INL (M2), 7/31/2016
  - X-ray and 3D CT analysis



MPFD components prior to final assembly



X-ray (left) and 3D CT (right) images of MPFD showing wire connections



Micro-focus 3D CT scan of MPFD

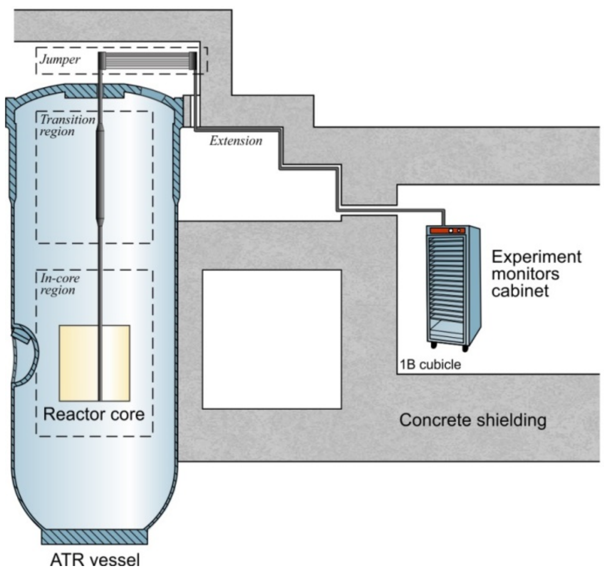
Accomplishments

FY16 Milestones, Deliverables and Outcomes

- Issue "NEET Enhanced Micro-Pocket Fission Detector for High Temperature Reactors - FY16 Status Report, INL/EXT-16-40053" (M2), 9/29/2016
- Numerous papers and presentations of the HT MPFD technology

Crosscutting Accomplishments

- ***Advanced Gas Reactor (AGR) Deployment***
  - *AGR-5/6/7 Irradiation in ATR (funded by AGR)*
    - *HT MPFD with Type N thermocouple*
    - *Irradiation for entire test (~3 years)*
    - *Irradiated with other advanced sensors*
    - *Electronics cabinet at ATR*

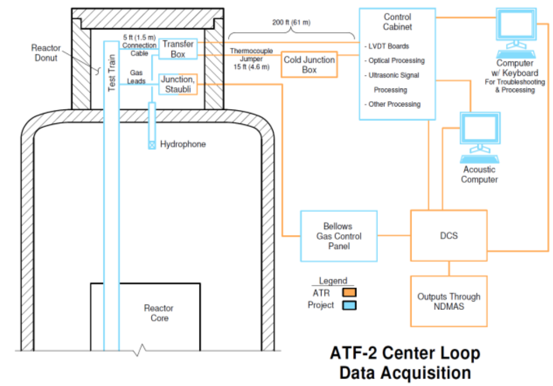


ATR instrumentation layout for AGR 5/6/7

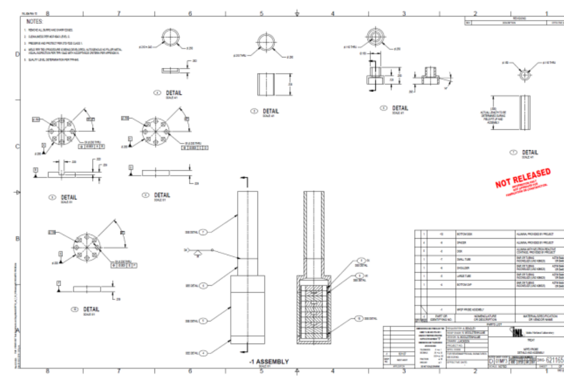
Electronics Cabinet for AGR 5/6/7

Crosscutting Accomplishments

- ***Accident Tolerant Fuel (ATF) Deployments***
  - *ATF-2 Sensor Qualification Test in ATR Irradiation*
    - *HT MPFD (Irradiation funded by ATF-2)*
    - *Irradiation for one ATR cycle*
    - *Irradiated with other advanced sensors*
  - *ATF-3 multi-Static Environment Rodlet Transient Test Apparatus (multi-SERTTA) Irradiation*
    - *TREAT-designed MPFD (Irradiation funded by ATF-3)*
    - *Irradiation for low power calibration and high power transient*
    - *Four fission chambers to capture transient*
    - *No thermocouple*



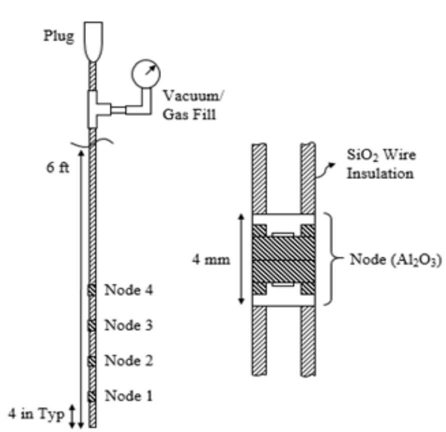
ATF-2 Data Acquisition layout

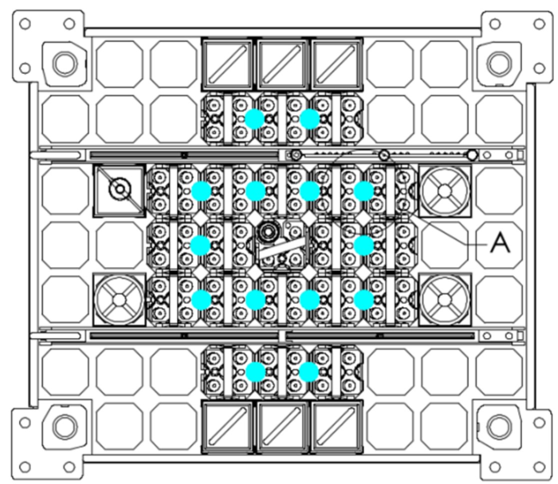


ATF-3 MPFD drawings

Crosscutting Accomplishments

- **_Nuclear Energy Advanced Modeling and Simulation (NEAMS) Deployment_**
  - *A Transient Reactor Physics Experiment with High-Fidelity, 3-D Flux Measurements for Validation and Verification*
    - *Kansas State University led: Dr. Jeremy Roberts*
    - *University of Wisconsin-Madison reactor*
    - *Specially designed MPFD wands deployed for steady state and transient response*





MPFD wands (left) and locations in University of Wisconsin-Madison reactor (right)

Technology Impact

- **Advanced sensor for DOE-NE programs requiring real-time flux detection**
  - Flexibility (variable sensitivities, lifetimes and detector responses)
  - Neutron sensitive (BOTH fast and thermal)
  - Temperature sensitive with integral high-temperature thermocouple
  - Compact size
  - Radiation resistant
  - High temperature and pressure resistant
  - High accuracy, high resolution
  - Fast response
  - Long lifetime
- **State-of-the-art sensor positions U.S. for leadership in irradiation testing**
  - Minimizes flux perturbation associated with typical real-time in-core sensors
  - Eliminate uncertainty with transient correction factors
  - Higher fidelity data for modeling and simulation of materials and fuels[1]
  - Permits 3D modeling and triangulation of data for validation[1]

[1] J. Roberts, et al. , "FY15 NEUP: A Transient Reactor Physics Experiment with High-Fidelity, 3-D Flux Measurements for Validation and Verification"

Conclusion

- Compact, multi-purpose advanced neutron detector is essential for supporting accelerating data collection from various irradiation testing programs

- HT MPFD will be deployed by several DOE-NE irradiation testing programs in FY17 and beyond

- FY16 HT MPFD milestones completed successfully and on schedule