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Performance Demonstration in Operational Conditions

Advanced Sensors and Instrumentation Annual Webinar

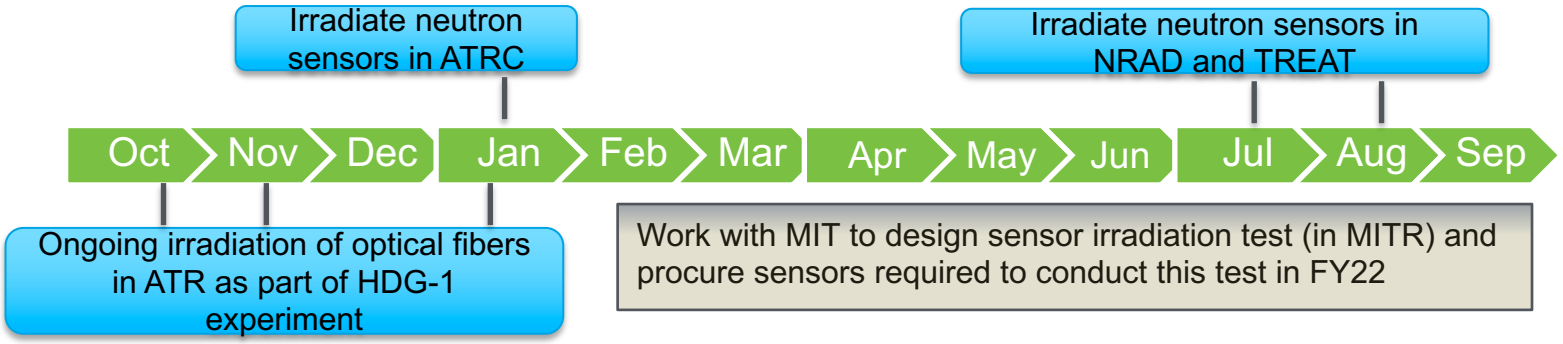
November 5, 2020

Joe Palmer

INL Reactor Experiments Design

Project Overview*

- Objective
  - Test and demonstrate in-pile instrumentation in conditions similar to those expected to be seen in service
- Participants (FY20, FY21)
  - Joe Palmer, Kevin Tsai, Calvin Downey, Kelly McCrary, Troy Unruh, Michael Reichenberger, Loic BARBOT (CEA)
- Schedule (FY21)



***Performance Demonstration in Operational Conditions** includes a separate effort to Procure Halden Fuel Refabrication Equipment, which will be covered later in this presentation*

Technology Impact

- Advanced instrumentation enables testing of nuclear fuels and materials in support of the US advanced nuclear technology industry
- The early part of sensor development can be done outside of the reactor environment, but full technical readiness requires experience gained from in-core performance testing
- Customers usually have only one shot to conduct their irradiation experiments
- Therefore it is vital to demonstrate newly-developed instruments in operational conditions, prior to incorporating them into long-term high-value experiments

Milestones

FY20-21 Milestones

Milestone	Due Date	Status
Hold final design review for ATRC Instrumentation Experiment	5/21/2020	Completed on time
Complete fabrication of ATRC Instrumentation Experiment	9/21/2020	Completed on time
Perform irradiation test on ATRC Instrumentation Experiment	3/25/2021	On schedule
Perform high temperature neutron irradiation test on neutron flux sensors to aid the development of temperature compensation performance models	9/20/2021	On schedule

Summary of accomplishments FY20

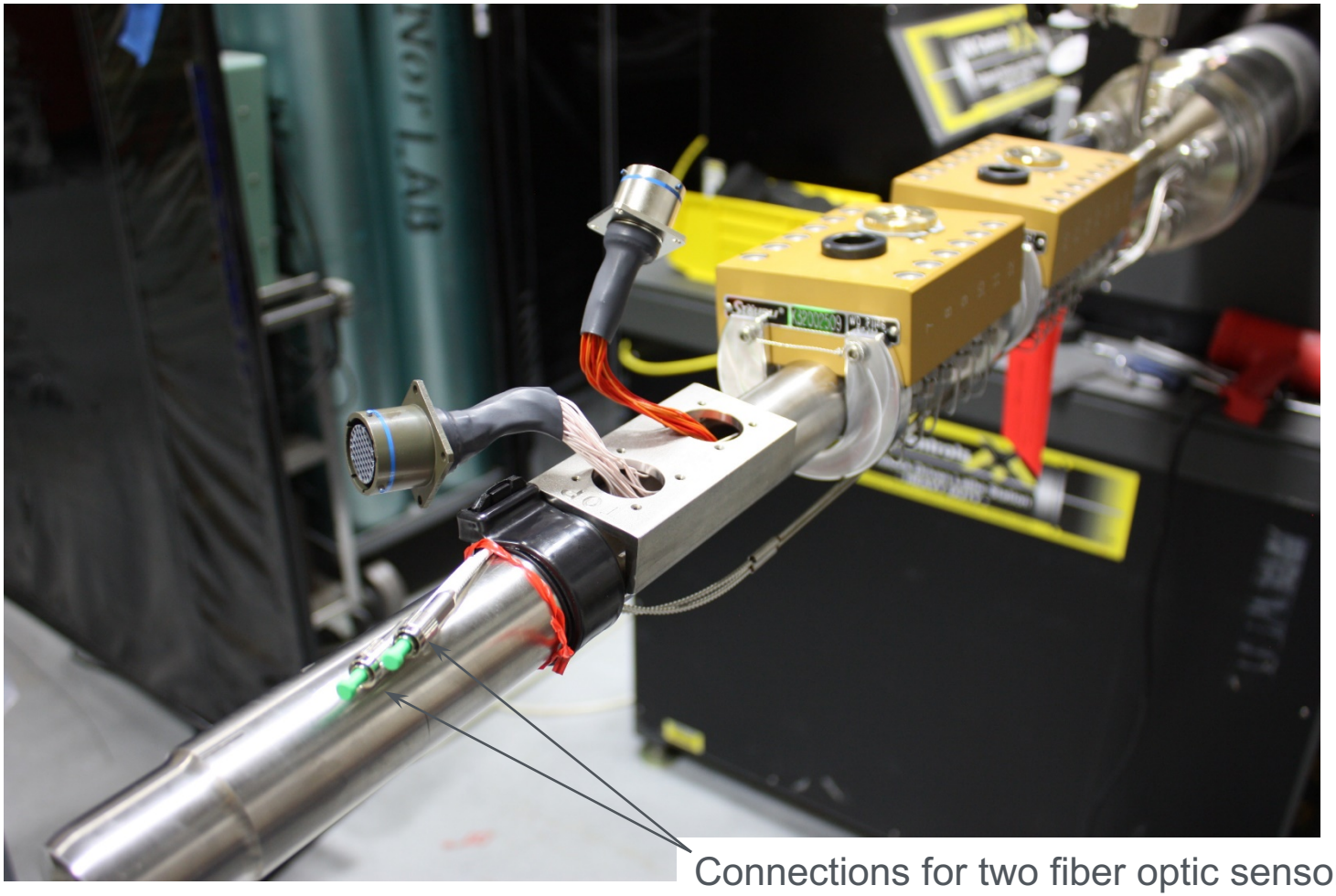
- Installed two optical fiber-based temperature sensors in the HDG-1 experiment and began irradiation of these instruments
- Designed and fabricated ATRC Instrumentation Experiment configured to irradiate three types of active neutron flux monitors: Self Powered Neutron Detectors (SPNDs), MicroPocket Fission Detectors (MPFDs), and fission chambers; as well as a suite of passive neutron dosimetry (thermal, epithermal, and fast), which were selected to confirm the measurements of the active instruments

Summary of accomplishments FY20

- Conducted “concurrent testing” of neutron sensors in the TREAT reactor
- Program accomplishments paved the way to an NSUF funding grant to irradiate SPNDs and MPFDs in the MIT reactor at light water reactor prototypical temperature and flux (FY21/22)
- Developed a “retractable sensor” concept which would drive a sensor in and out of the core section of an irradiation experiment to extend life and calibration – two university teams adopted this idea for their undergraduate Capstone projects

Accomplishments

Fiber optic sensors installed in HDG-1

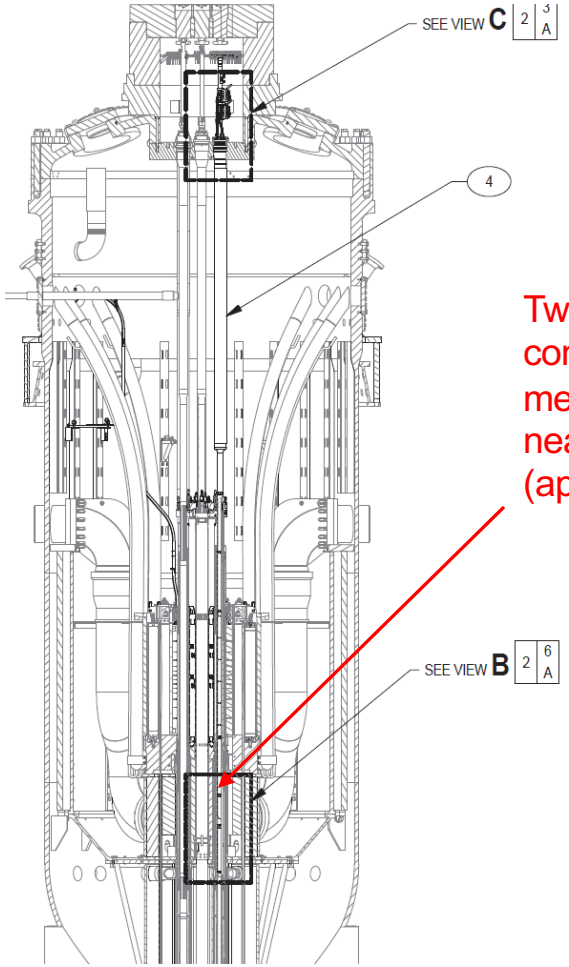


Connections for two fiber optic sensors at the top of the HDG-1 test

Accomplishments

Fiber optic sensors installed in HDG-1

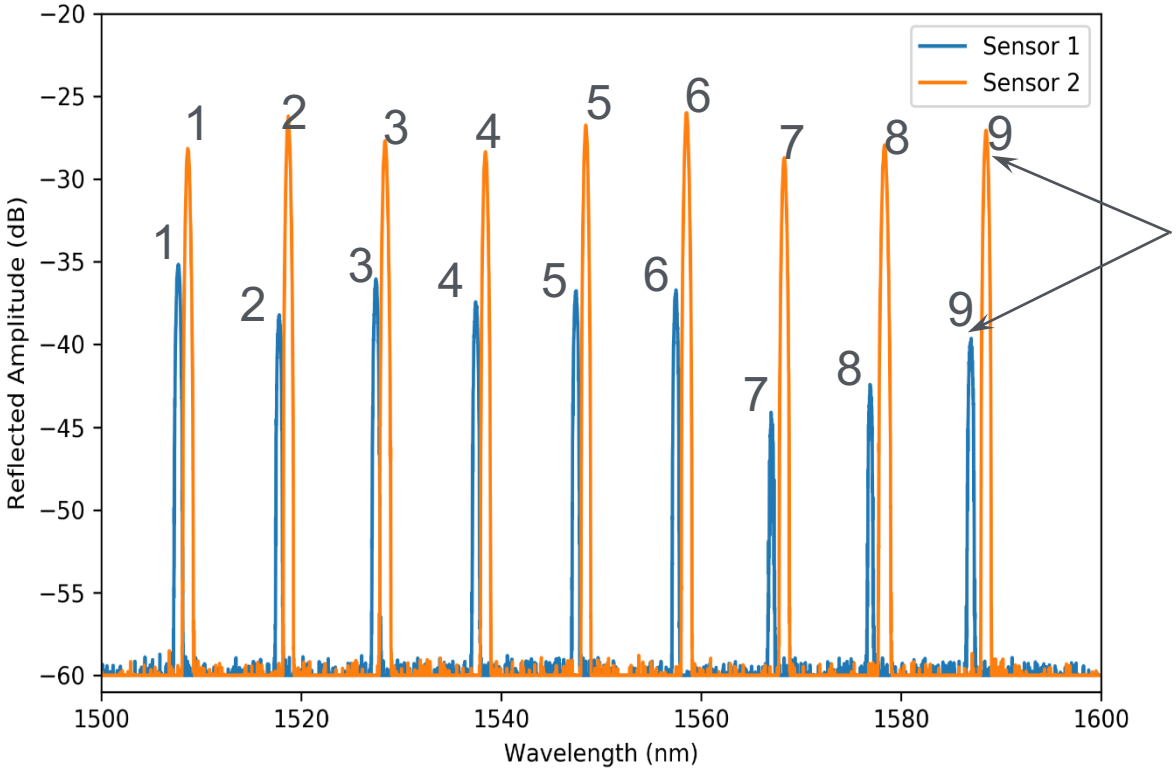
HDG-1 (High Dose Graphite-1) began irradiation in ATR August 2020



Two optical fibers and comparison thermocouple measure temperatures near top of core region (approx. 530°C)

Accomplishments

Fiber optic sensors installed in HDG1

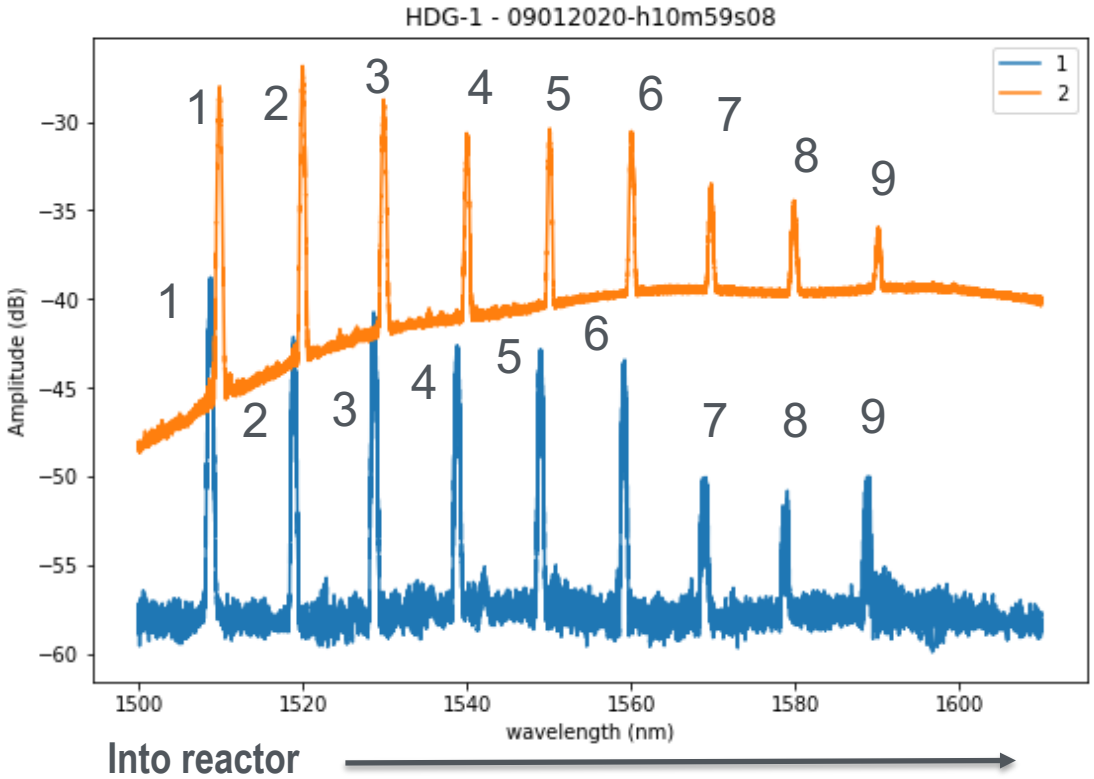


Reflected spectrum of each sensor taken after installation in HDG-1 (prior to irradiation)

- Each fiber has 9 Fiber Bragg Gratings (FBGs).
- Temperature measurements can be made at each FBG by tracking the center wavelength of each of the peaks.
- Sensor 1 has a lower amplitude than Sensor 2 because it was annealed at a higher temperature than Sensor 2.

Accomplishments

Fiber optic sensors installed in HDG1

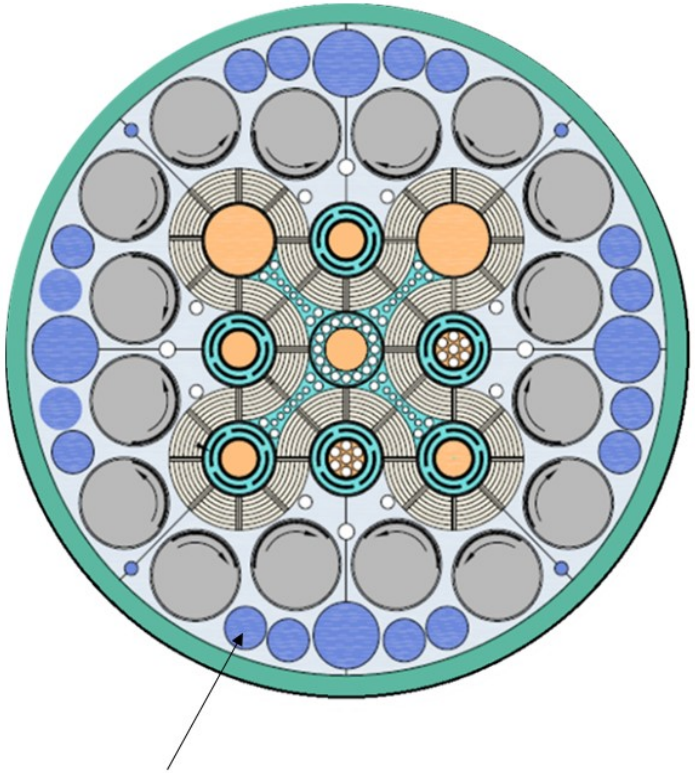


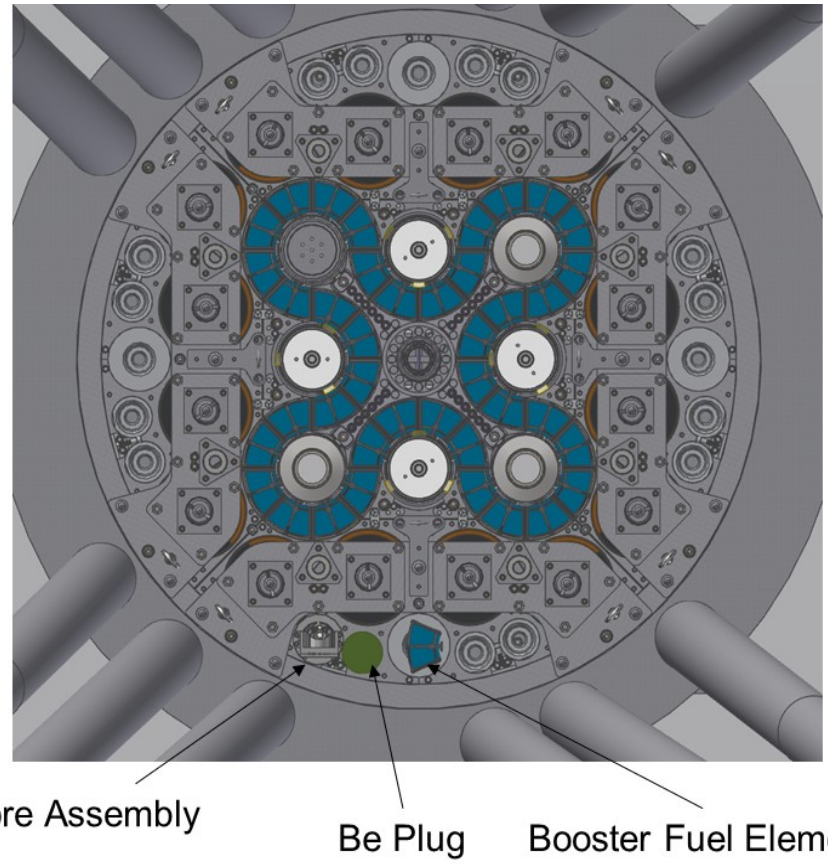
Reflected spectrum of each sensor taken after 5 days of full power irradiation in HDG-1

- Sensor 1 was annealed at a higher temperature than Sensor 2.
- Both sensors are attenuating towards the ends of the fibers where the fibers are further into the flux field

Accomplishments

ATRC instrumentation experiment ready to insert

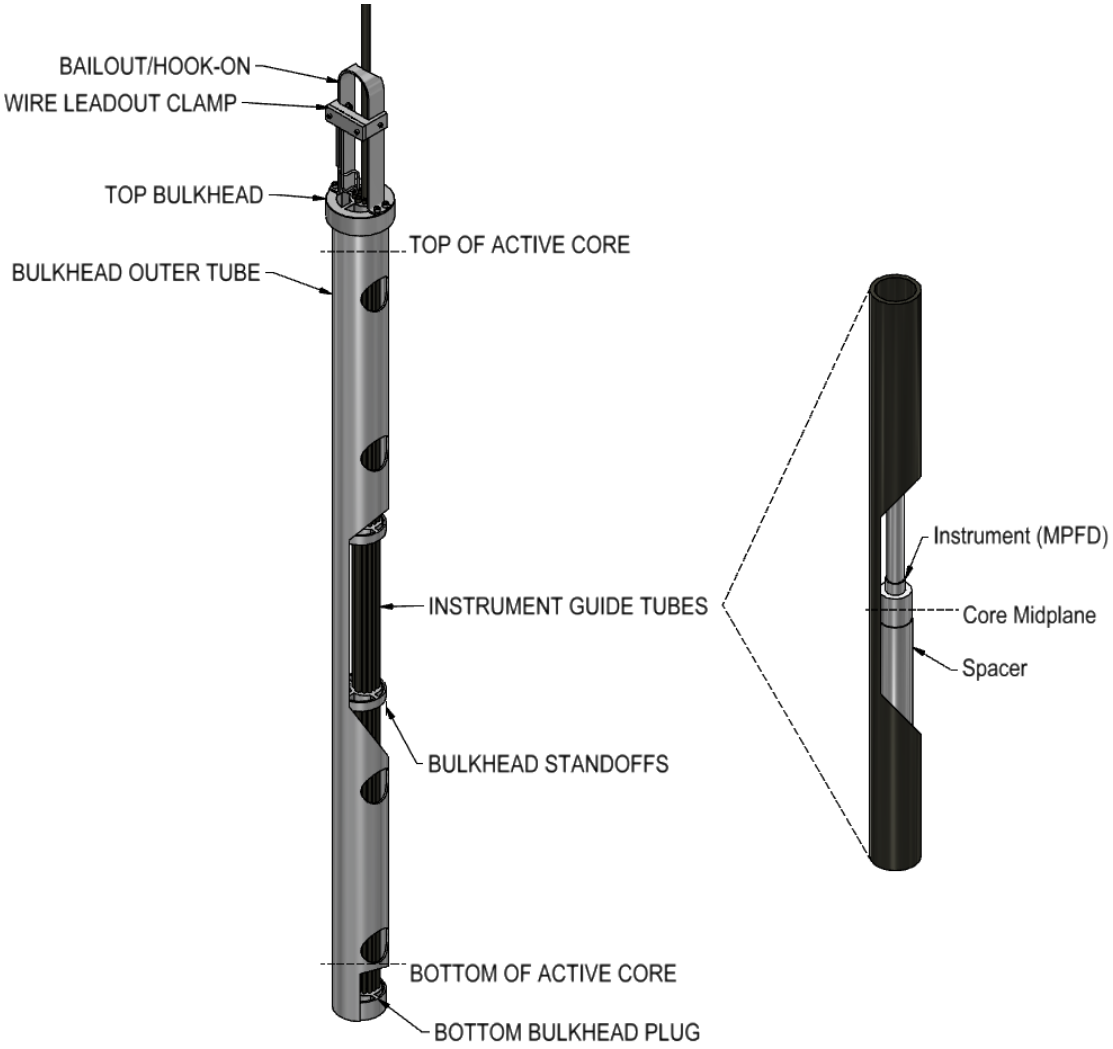




Instrument testing in ATRC provides a bridge towards improved sensors in ATR, and enhances experimental capabilities that were identified in the Halden Gap Assessment

Accomplishments

ATRC instrumentation experiment ready to insert



Accomplishments

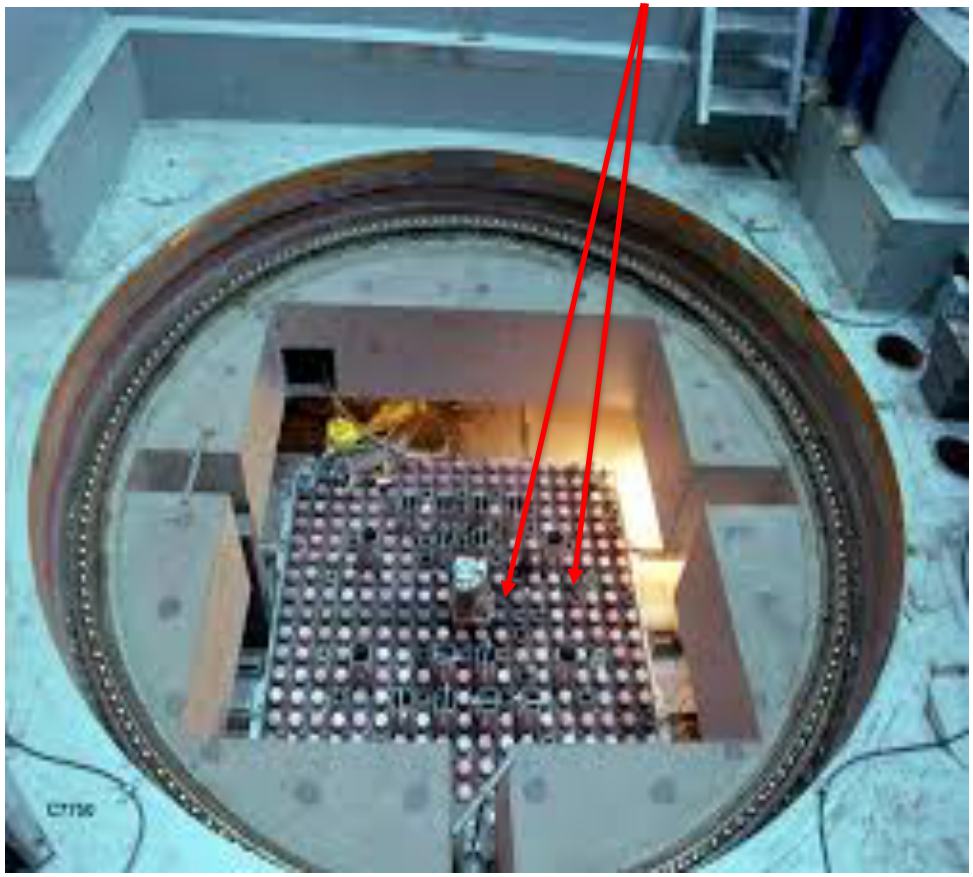
ATRC instrumentation experiment ready to insert

INL Assembly 822717-1 complete and with green tag signifying Quality acceptance

Accomplishments

TREAT concurrent testing

Developmental sensors are placed in cooling channels around fuel assemblies, rather than in experiments themselves. This approach lowers costs and does not interfere with high-value customer experiments.

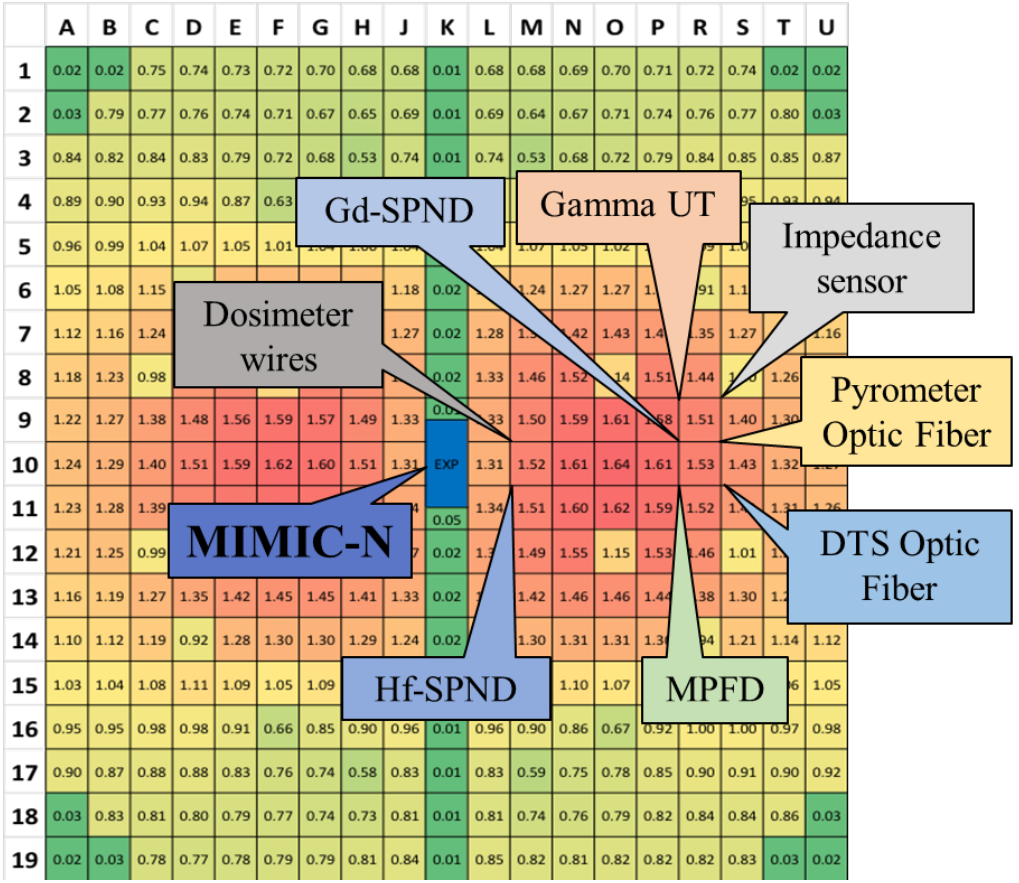


Accomplishments

TREAT concurrent testing

Concurrent Testing Sensors in FY20

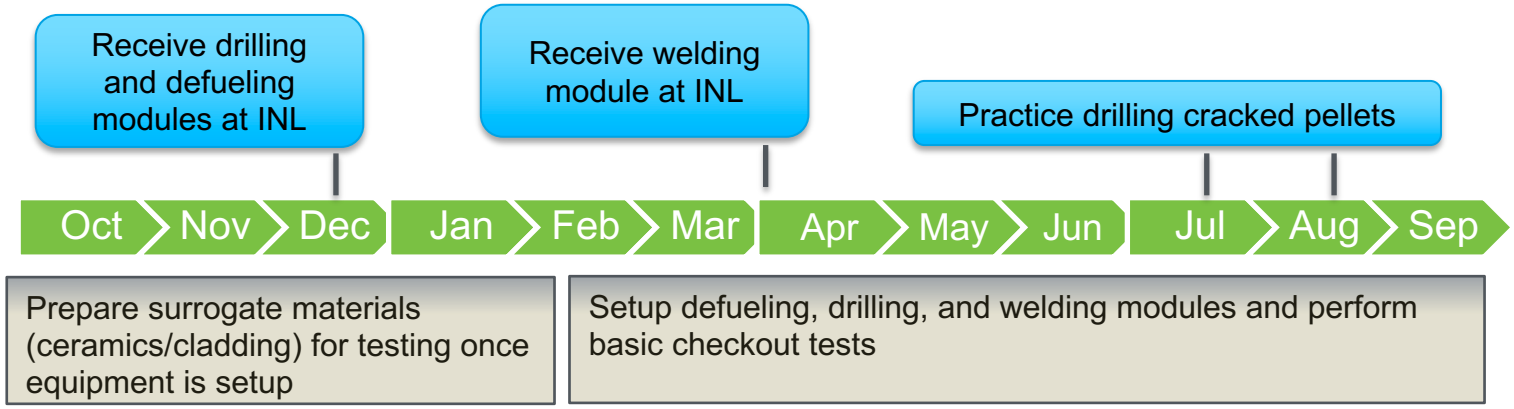
- Gd-SPND
  - Collecting data for core characterization and data reference since April 2018
- Gamma Ultrasonic Sensor
  - Planned in FY20—Irradiation in October
- Impedance Sensor
  - Support boiling Detector in SERTTA experiments
- Pyrometer
- Distributed Temperature Sensing Fiber
  - FY20 ASI fiber benchmark
- MPFD
- HF-SPND
  - Provide near experiment neutron flux
- MIMIC-N – Neutron Sensor Benchmark
  - Gd-SPNDs
  - MPFD
  - Dosimetry (conventional & advanced manufactured)



TREAT core map with relative flux ratios

Project Overview

- Objective
  - Capture critical technology created by Halden Reactor Project to reinstrument irradiated fuel rodlets, and further this technology to enable incorporation advanced instrumentation: fiberoptics, LVDTs, ultrasonic based sensors
- Participants (FY20, FY21)
  - Joe Palmer, Calvin Downey, Spencer Parker, Ashley Lambson
- Schedule (FY21)



FY21 Milestones

Milestone	Due Date
Receive prototype drilling and defueling modules from Halden	1/22/2021
Receive prototype welding module from Halden	6/25/2021
Complete system check out testing of the three prototype equipment modules from Halden	9/30/2021

Summary of accomplishments FY20

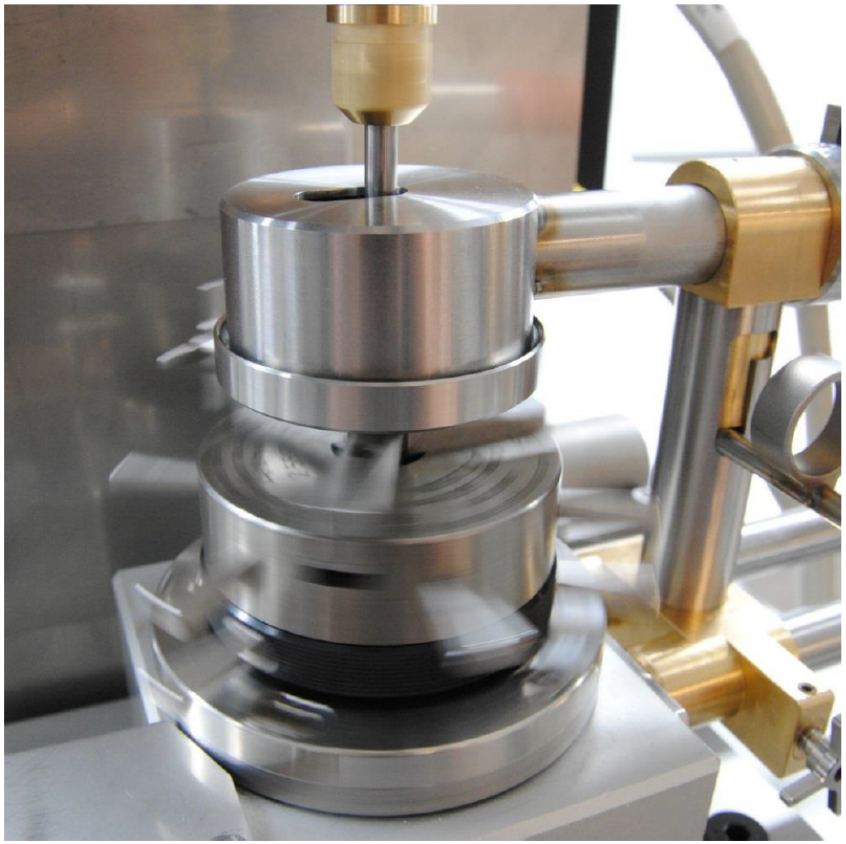
- Placed contract with Halden Reactor Project (now IFE) to produce three prototype equipment modules:
  1) Defueling module – removes fuel from both ends of rodlet as well as oxides in preparation for welding
  2) Drilling module – drills 50 mm deep hole to allow placement of thermocouple (in the future advanced instrumentation)
  3) Welding module – welds end plugs on each end of rodlet and performs helium leak check
- Followed fabrication of defueling and drilling modules
- Procured surrogate cladding and fuel material (CeO_2) in preparation for testing equipment after arrival

Technology Impact

- For decades, the Halden Boiling Water Reactor (HBWR) in Norway has been a key resource for assessing nuclear fuels and materials behavior to address performance issues and answer regulatory questions.
- The HBWR was shut down in 2018. In order to avoid the loss of the unique experimental techniques developed at Halden, INL is procuring equipment modules designed to reinstrument sections of LWR fuel rods prior to irradiating in a test reactor.
- This is part of a broader effort to transfer the expertise developed at Halden to other relative facilities such as TREAT and ATR.
- This fuel testing is key to advancing and qualifying new light water reactor technologies.

Accomplishments

Defueling module in action at Halden

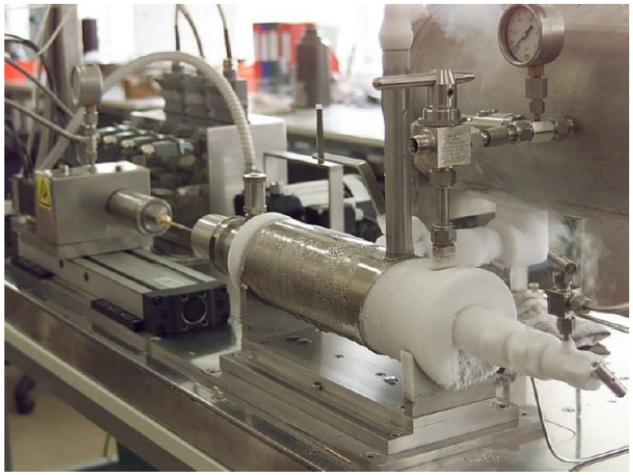


Defueling of fuel rod

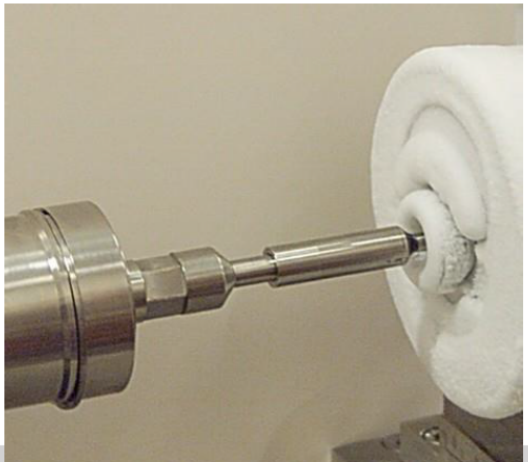
Defueling finished

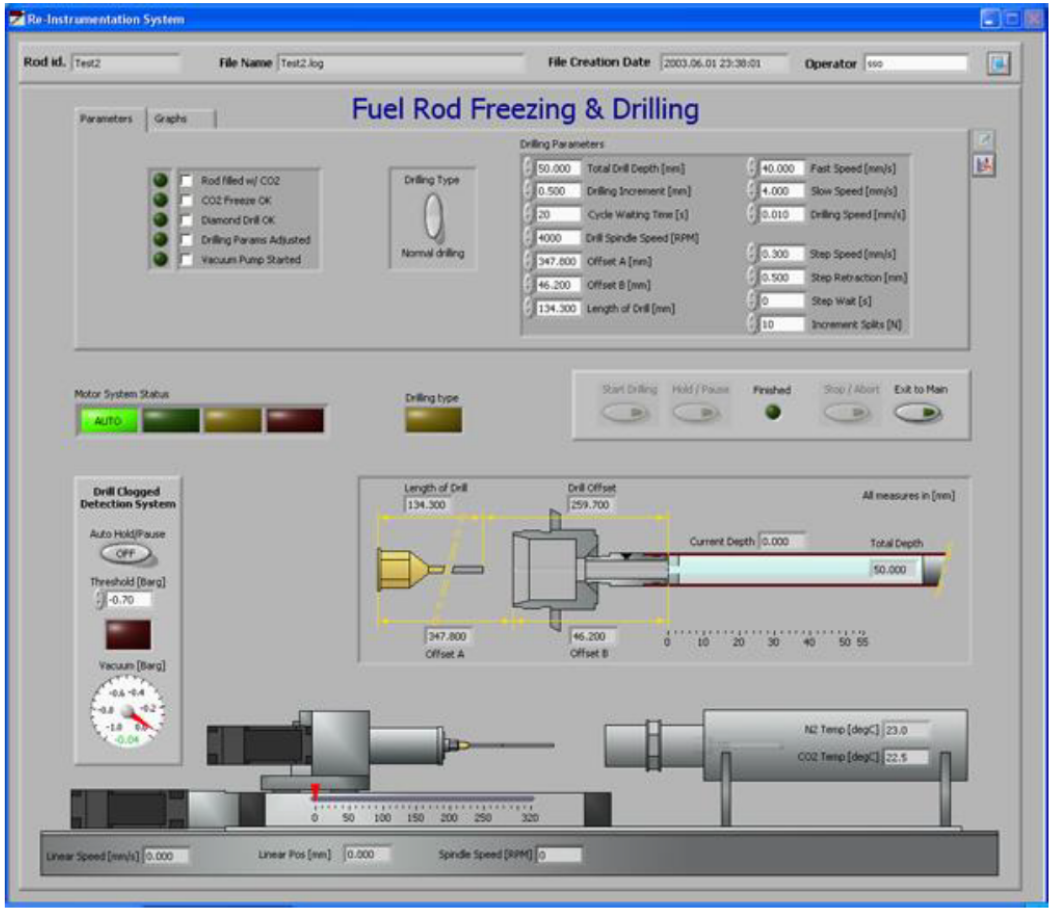
Accomplishments

Drilling module in action at Halden



Drilling equipment in operation





User interface for the freezing and drilling unit

Summary

- *Customers usually have only one shot to conduct their irradiation experiments*
- *Therefore it is vital to demonstrate newly-developed instruments in operational conditions, prior to incorporating them into long-term high-value experiments*
- *During FY20 this program began testing optical fiber temperature probes in ATR, conducted concurrent testing in TREAT, fabricated and assembled an experiment for ATRC, and ordered three equipment modules from Halden for reinstrumentation of irradiated fuel*
- *Questions?*

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