ATR NSUF In-Pile Tube Experiments

June 9, 2011

Craig Tyler
Experiment Design & Analysis
Nuclear Science & Technology

(INL/MIS-10-18989)

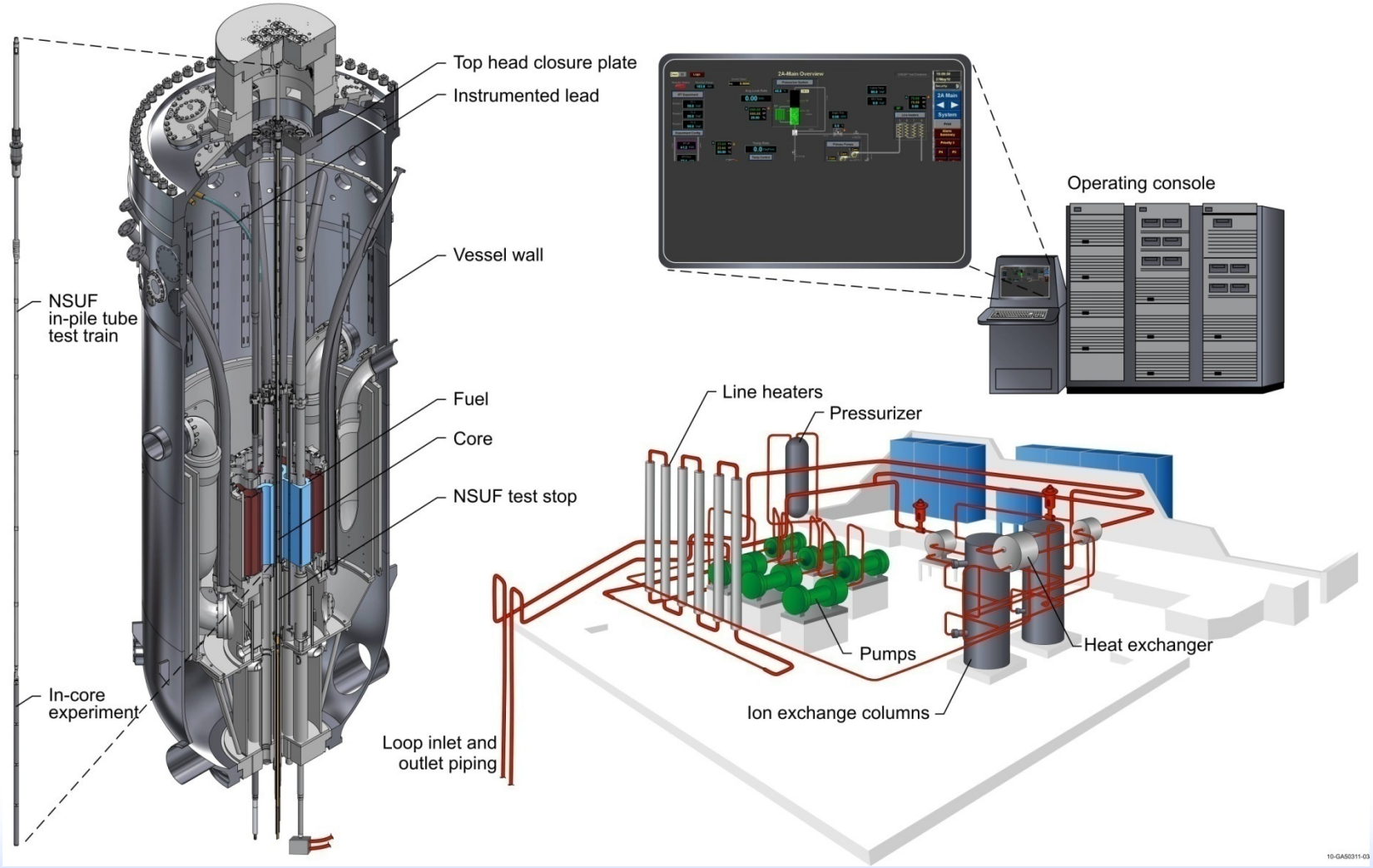
Idaho National Laboratory

Objective

- ***The objective of this presentation is to familiarize the audience with key aspects of the loop and in-pile tube test facility for future experiment planning:***
  - ***Loop Facility***
  - ***Experiment Considerations***
  - ***Test Train Interfaces***
  - ***Experiment Examples***
  - ***Loop Controls and Instrumentation***
- ***The focus will be on Test Train and Experiment Components***

LOOP FACILITY

Loop Facility



Pressurized Water Loops

- ***Five flux trap positions currently have pressurized water in-pile loop tests (1 large diameter, 4 standard diameter)***
- ***A sixth, NSUF, pressurized loop will be installed in the center flux trap and operational in late 2011***
- ***The experiment portion of the test loop that is within the reactor vessel is known as the In-Pile Tube, which is an insulated pressure vessel within the ATR reactor vessel***
- ***Each loop has its own temperature, pressure, flow & chemistry control systems that are located in the basement of the ATR building***

EXPERIMENT CONSIDERATIONS

Loop and Test Train Parameters

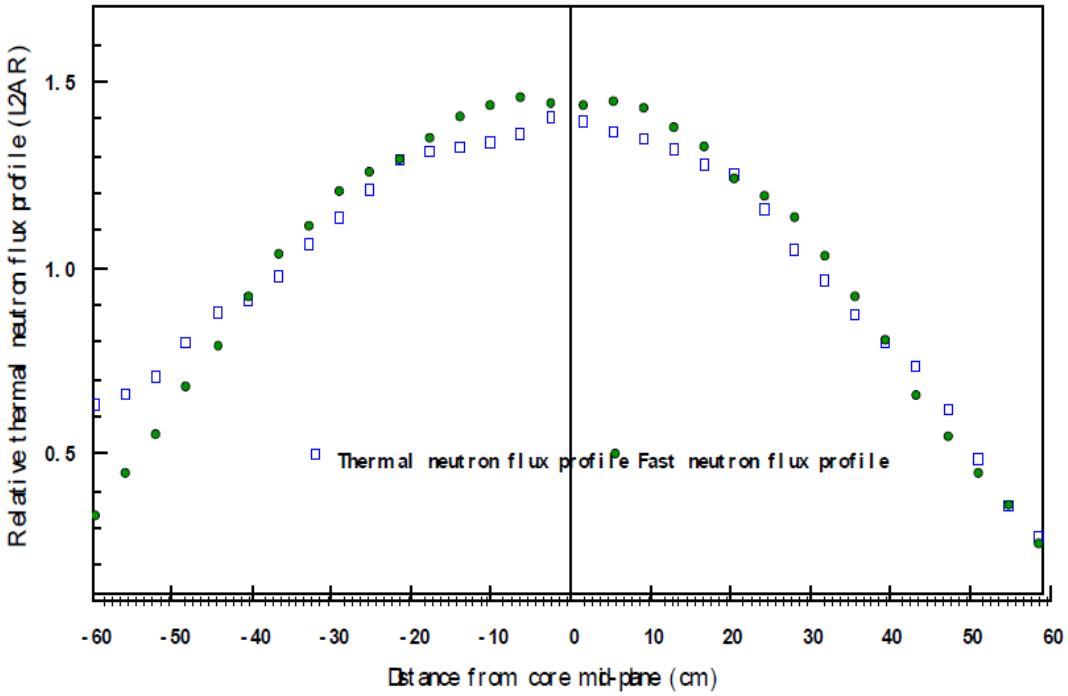
- Design Pressure: 2500 psig
- Nominal Operating Pressure: 2150 psig
- Typical Maximum Coolant Temperature: 315 C
- Example: Stainless target temperatures: 288 C
- Flow: 10-80 GPM
- Coolant Conductivity: 0.1-3.0 micro S/cm
- Flow Direction: Top down
- In-Pile Tube and Closure Plug: 347 stainless steel
- In-core holders: Zr-4, ASTM B351 or B353
- Zirc oxide on all holder surfaces

Initial Planning Input

- ***Specimen size & shape***
  - ***Must fit within 1.62 maximum inside diameter chamber within the Zirconium-4 holders***
- ***Target temperature limitations***
- ***Materials:***
    - ***Knowledge of materials required for ATR Analyses***
    - ***Prohibited:***
      - ***Unknown materials***
      - ***Explosive materials***
      - ***Cryogenic liquids***
      - ***Mercury, gold, copper, silver, chlorides-unless there is a special evaluation and approval by the INL***
- ***Desired Fluence***
  - ***Nominal Thermal Flux (2200 m/s)= 4.4E14 n/cm^2-s***
  - ***Nominal Fast Flux (E>1Mev)= 9.7E13 n/cm^2-s***
- ***Post Irradiation Examination***

Axial Flux Profile

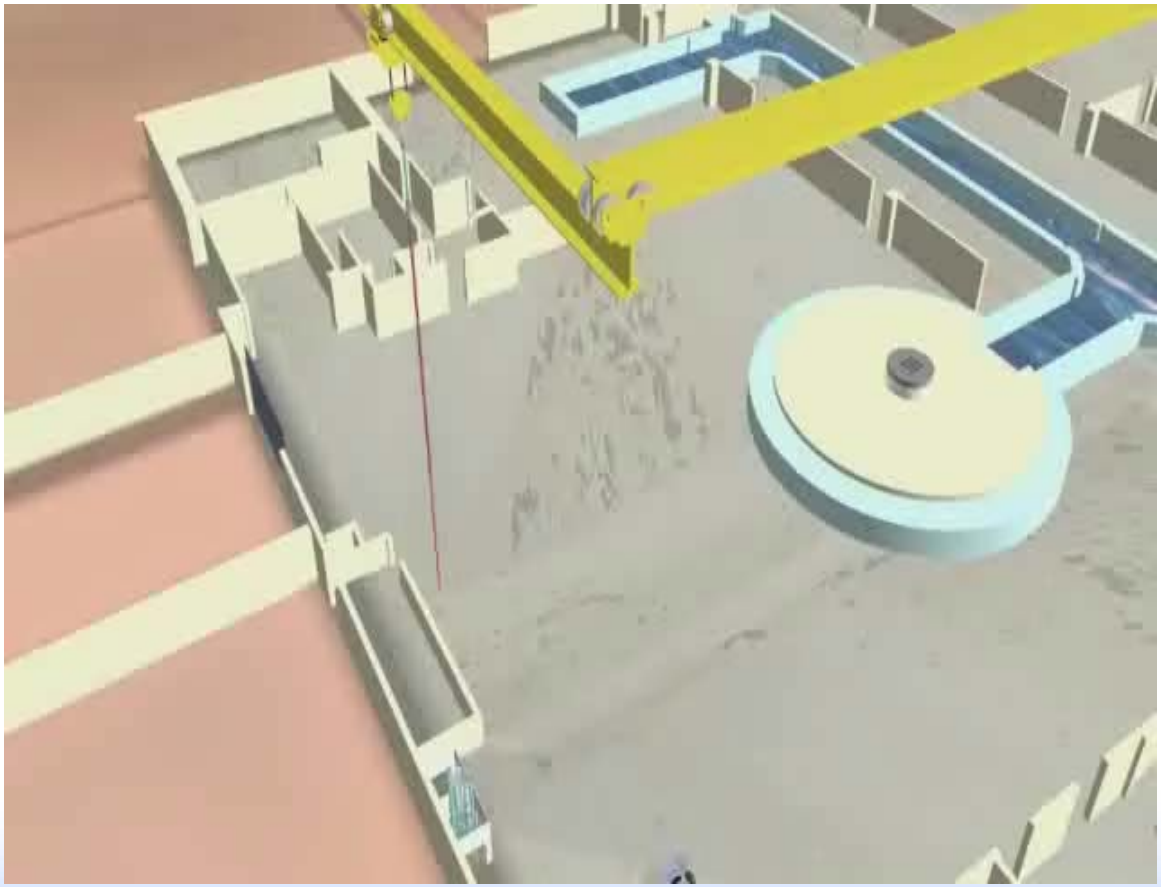
- ***Specimens and flux tailoring materials must maintain a relatively smooth axial flux profile without significant reactivity perturbations***



TEST TRAIN INTERFACES

Reactor and In-Pile Tube (IPT) Interface

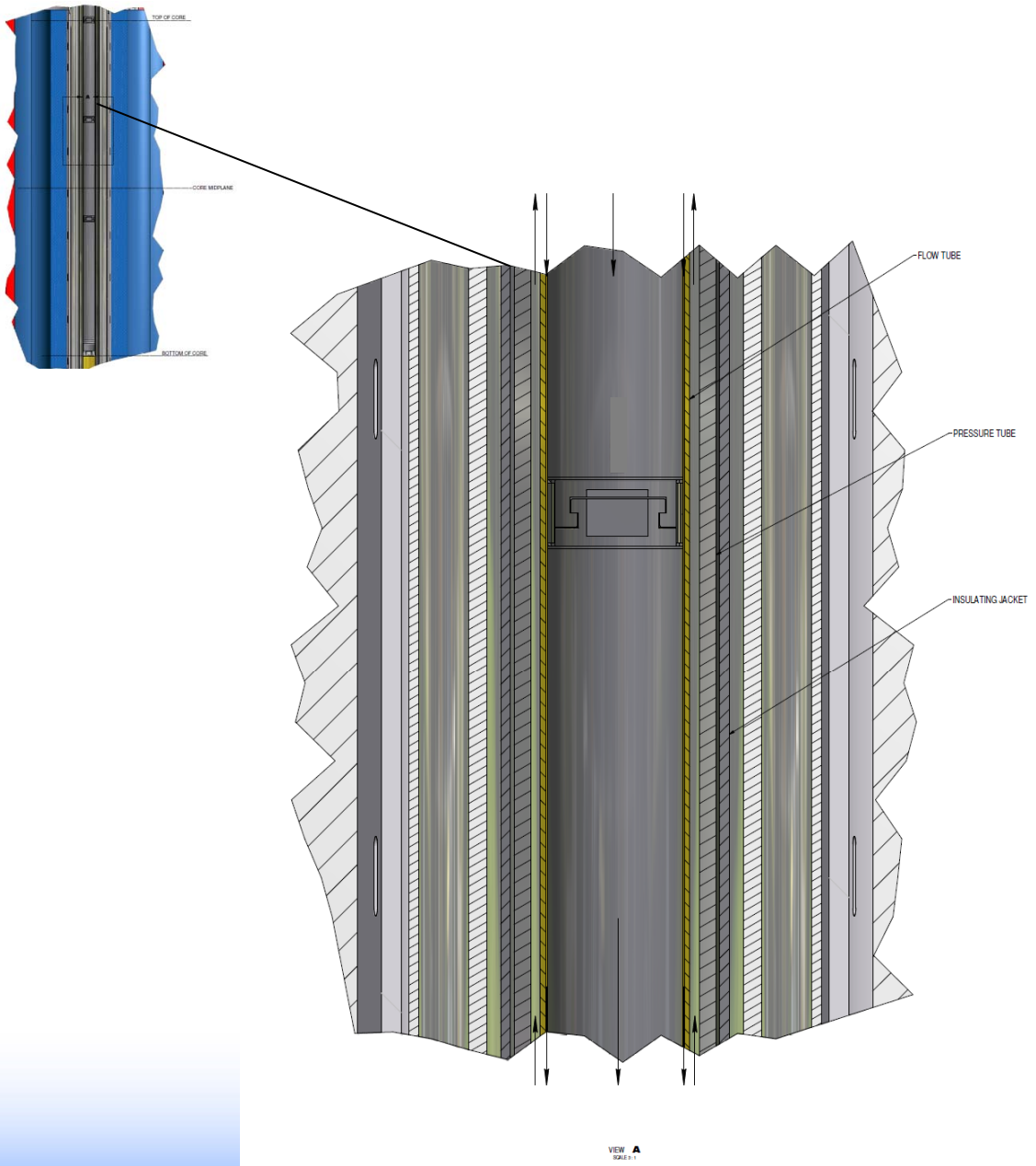
- ***The test train is inserted into the IPT***
- ***The slightly large cylinder near the top of the train is the closure plug, which is the only pressure boundary for the test train***
- ***Following irradiation, the IPT is pulled up into a shielded cask and moved to an adjacent canal disassembly station where the in-core, or experiment, portion of the test train is removed and sent to the canal working tray for reconfiguration or off-site shipment***



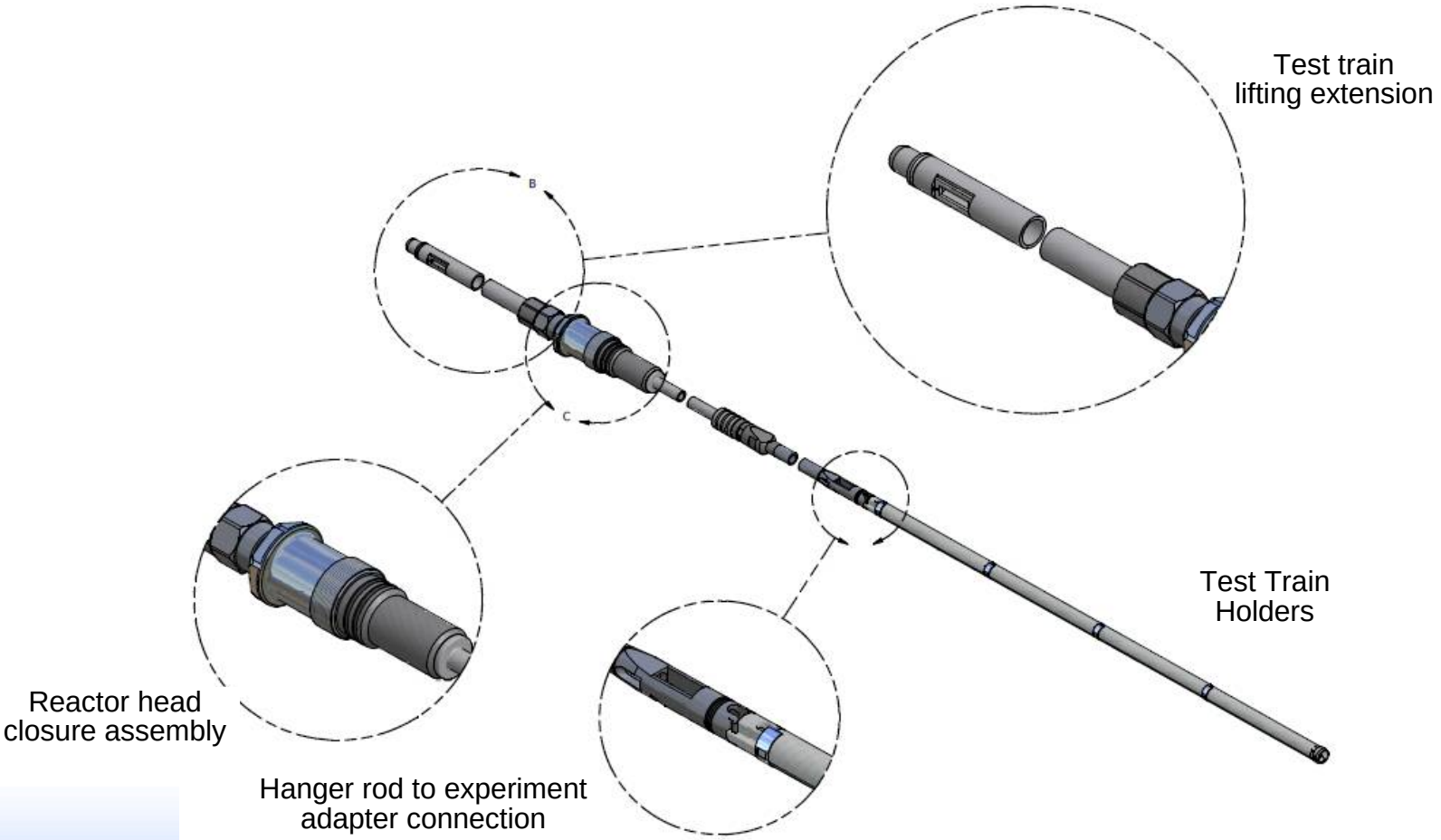
(double click for video)

In-Pile Tube (IPT) & Test Train Interface

- IPT assembly is designed, analyzed, and fabricated to the “intent” of the ASME Section III Code.
- Insulating jacket insulates the loop coolant from reactor primary coolant
- Pressure tube is a long, narrow pressure vessel
- Flow tube directs and provides inlet/outlet flow paths within the IPT
  - Most loops have bottom to top flow
  - The NSUF center flux trap IPT has top to bottom flow, simply because this is a previously existing plumbing arrangement for a prior test

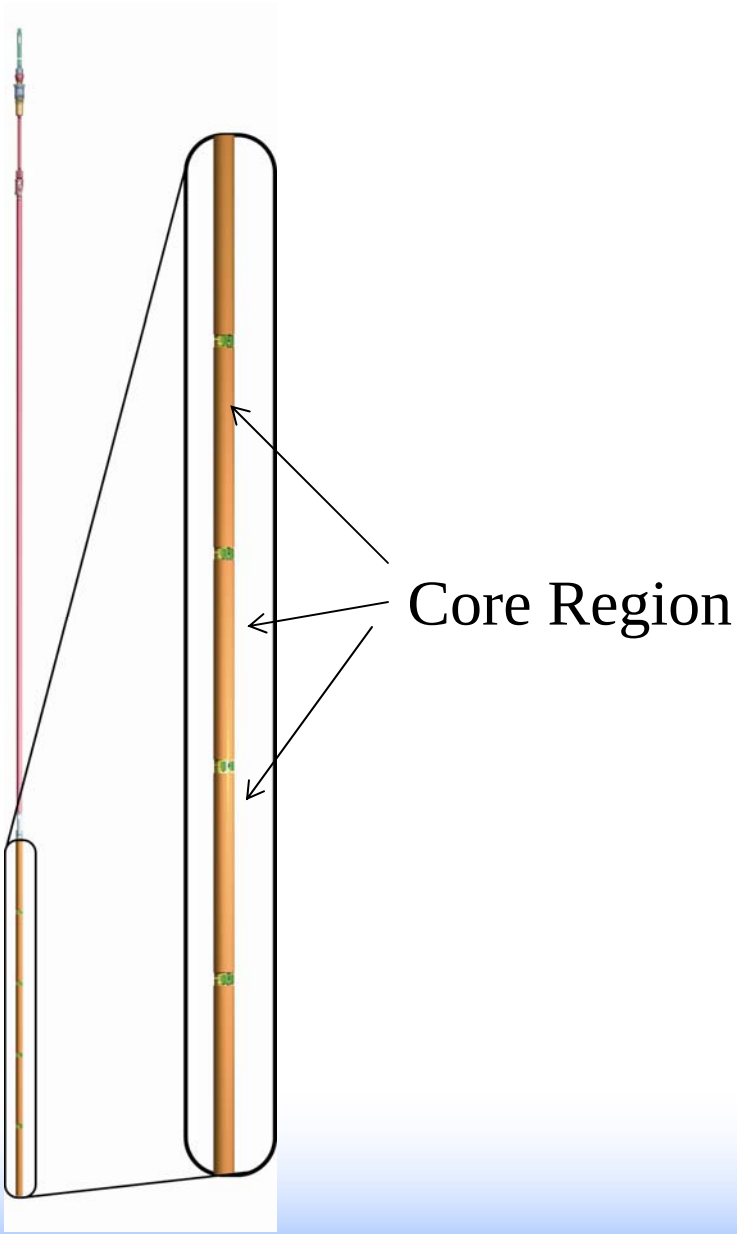


Test Train Components



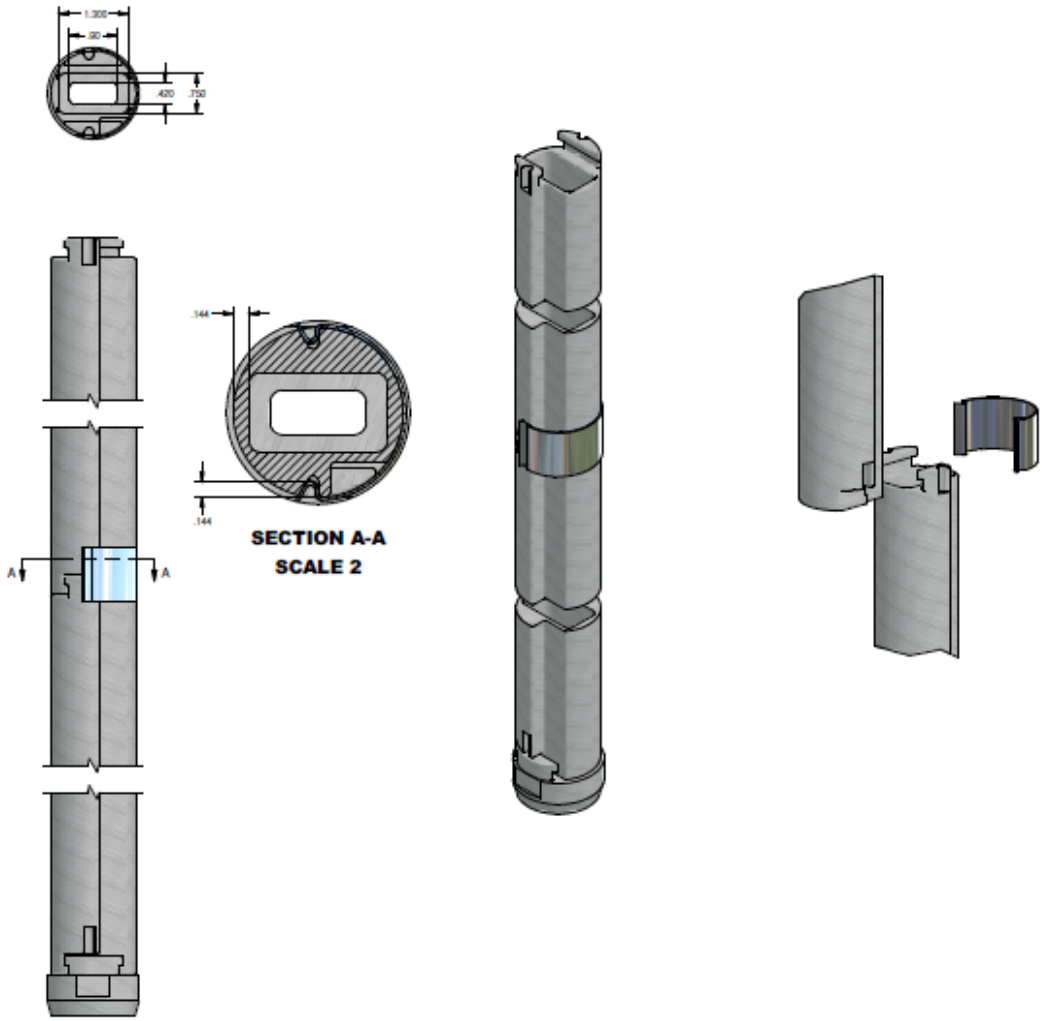
Holder Placement

- It is anticipated that most experiments will require removal of the entire experiment train, consisting of:
  - Alternative, above core holder(s) (~16”)
  - In-core holders can vary in length by 4-inch increments up to two feet in order to provide an overall in-core length of 48 inches
  - Alternative, below core holder(s) (~16”)



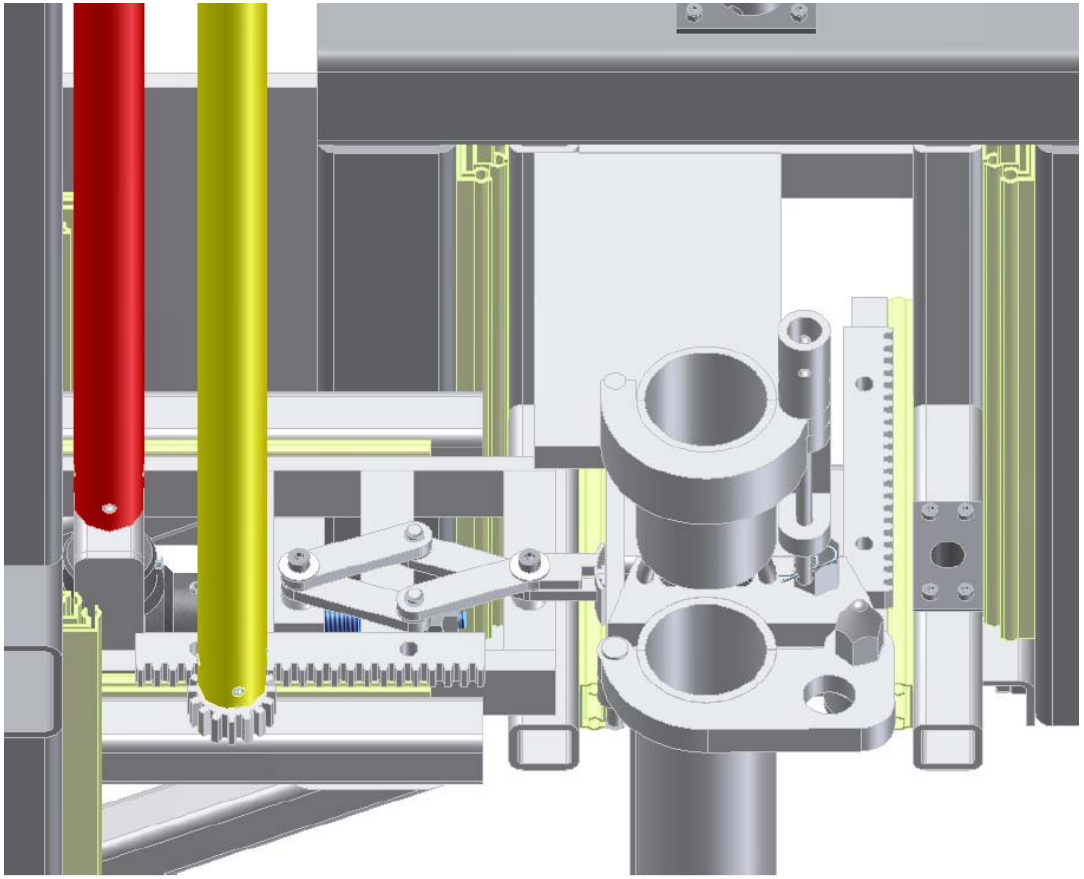
Zr-4 Holders

- Zr-4 holders are held together by sliding end connections together
- A clip keeps the holders aligned



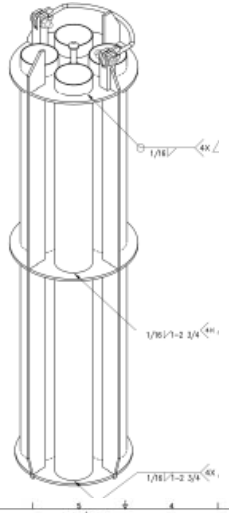
Clip Removal

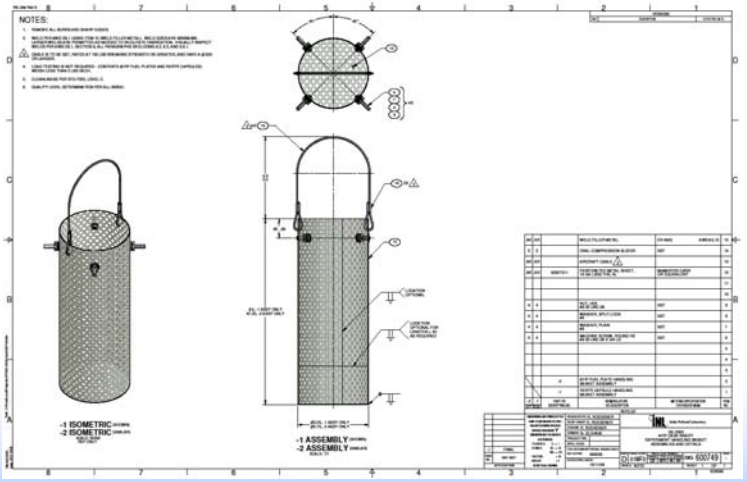
- During canal removal, one of the top holder clips is pulled off using a tool that is inserted into the clip
- The in-core test train, which is held by a bucket, is then taken to the canal working tray for reconfiguration or off-site shipment



Cask loading and Transportation

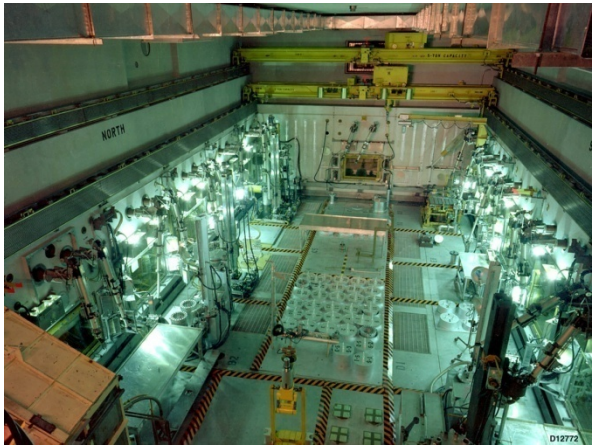
- Experiment holders will be loaded underwater in the ATR canal into the GE2000 or BRR cask, then transported to the MFC Hot Fuel Examination Facility
  - An insert fits within the cask
  - A basket with specimen containing holders fits within the insert
- Dry cell options will be considered in the future





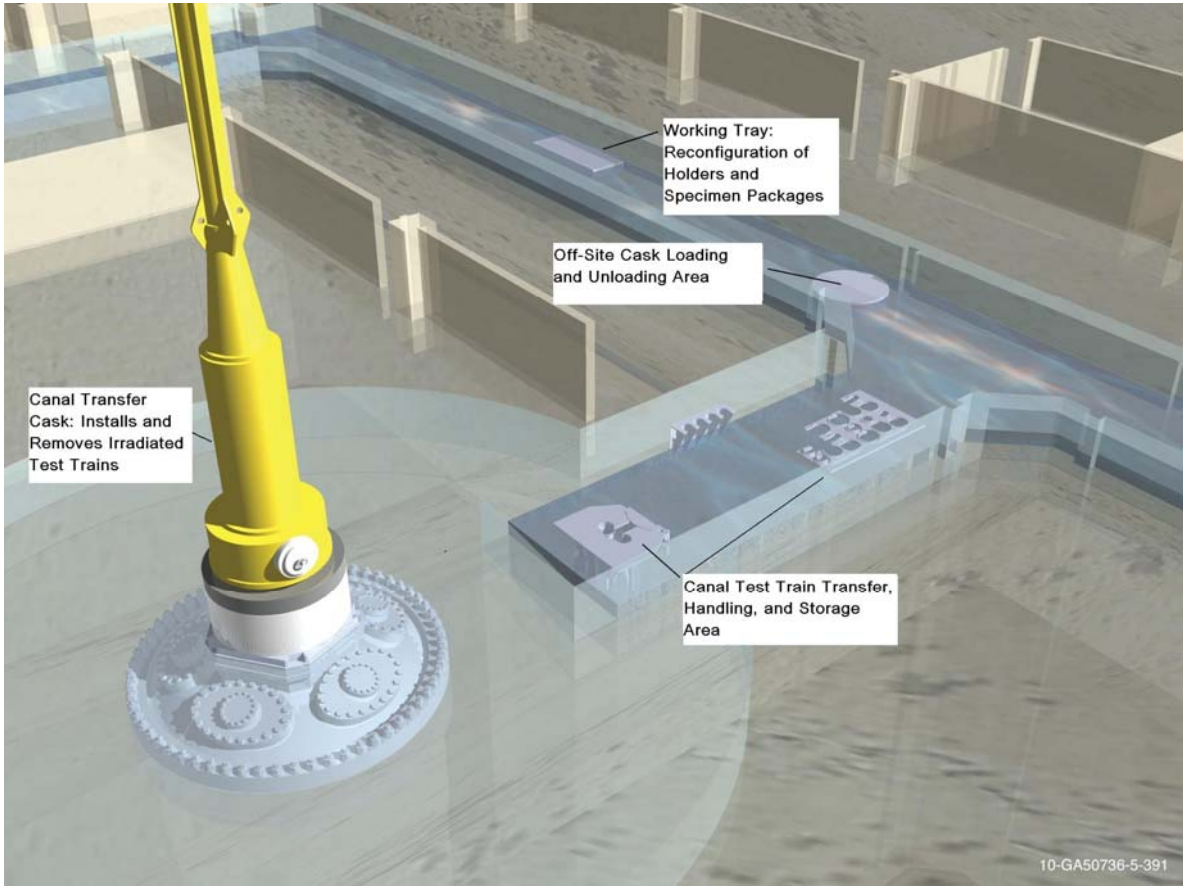
Previously Irradiated Material

- **Previously irradiated material that is of interest to researchers or regulators can be received via off-site casks, then prepared as specimen packages (targets) and placed in holders at the MFC Hot Cells (e.g., Hot Fuel Examination Facility (HFEF))**
- **Holders can then be transferred to the ATR canal via the GE-2000, loaded into the test train from the canal, then inserted into the ATR**



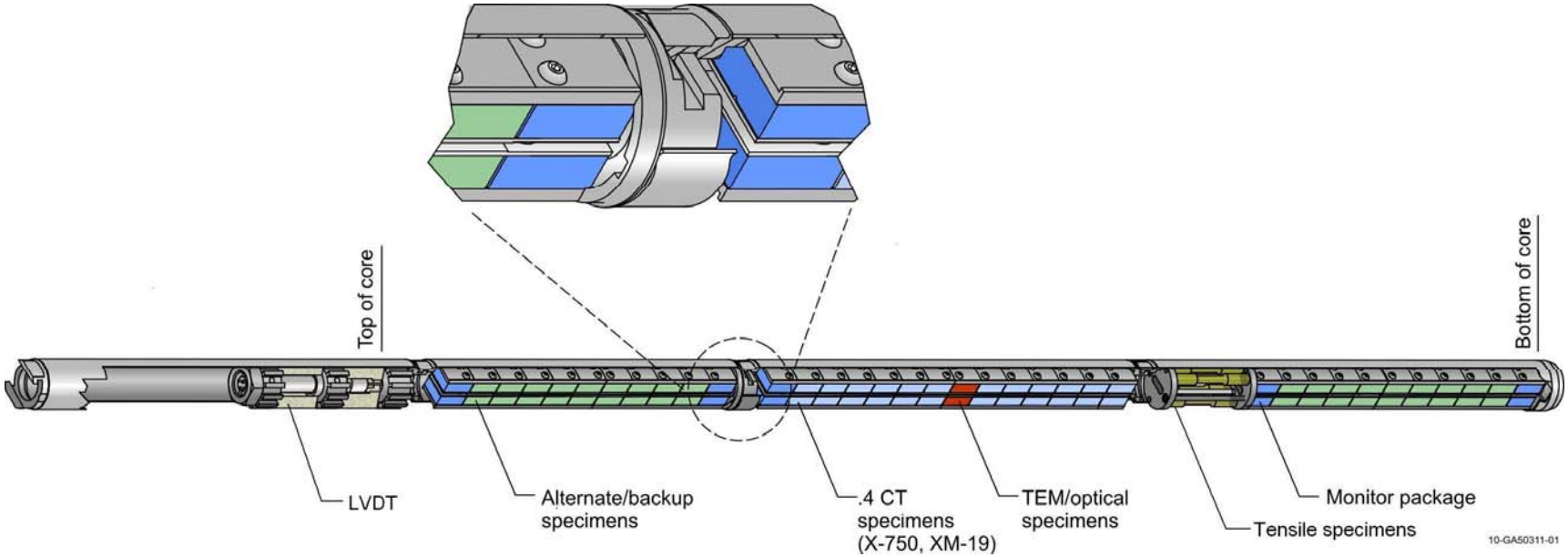
Canal Handling

- **Capsules with irradiated specimens (targets) can be transferred to or from ATR via the canal. For example:**
  - **Holders from MFC's HFEF hot cells can be transferred from GE-2000 at off-site cask loading/unloading area to the working tray**
  - **Holders then can be configured into the in-core portion of the test train at the working tray**
  - **Finally, the in-core portion of the test train is loaded onto the upper test train at the handling station and transferred to the ATR via the Transfer Cask (yellow)**
- **Again, any of these process flows can be reversed**



EXPERIMENT EXAMPLES

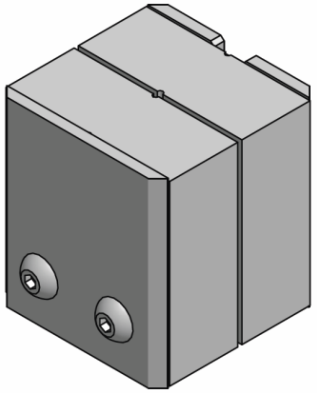
Example 1: 0.4 CT Specimens, X-750 and XM-19 Test Train Arrangement



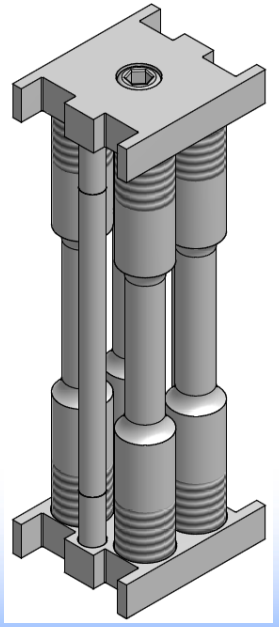
Experiment Package Design

- 0.4 CT specimens are sandwiched between two stainless plates with approximately 0.020 gap/washer between specimens
  - If needed, Hf and other materials can be added for flux tailoring or for finer temperature control
- Tensile specimens are retained between vertical stainless plates
  - If needed, a sleeve is added to increase temperature

0.4 CT Specimen Package



Tensile Package

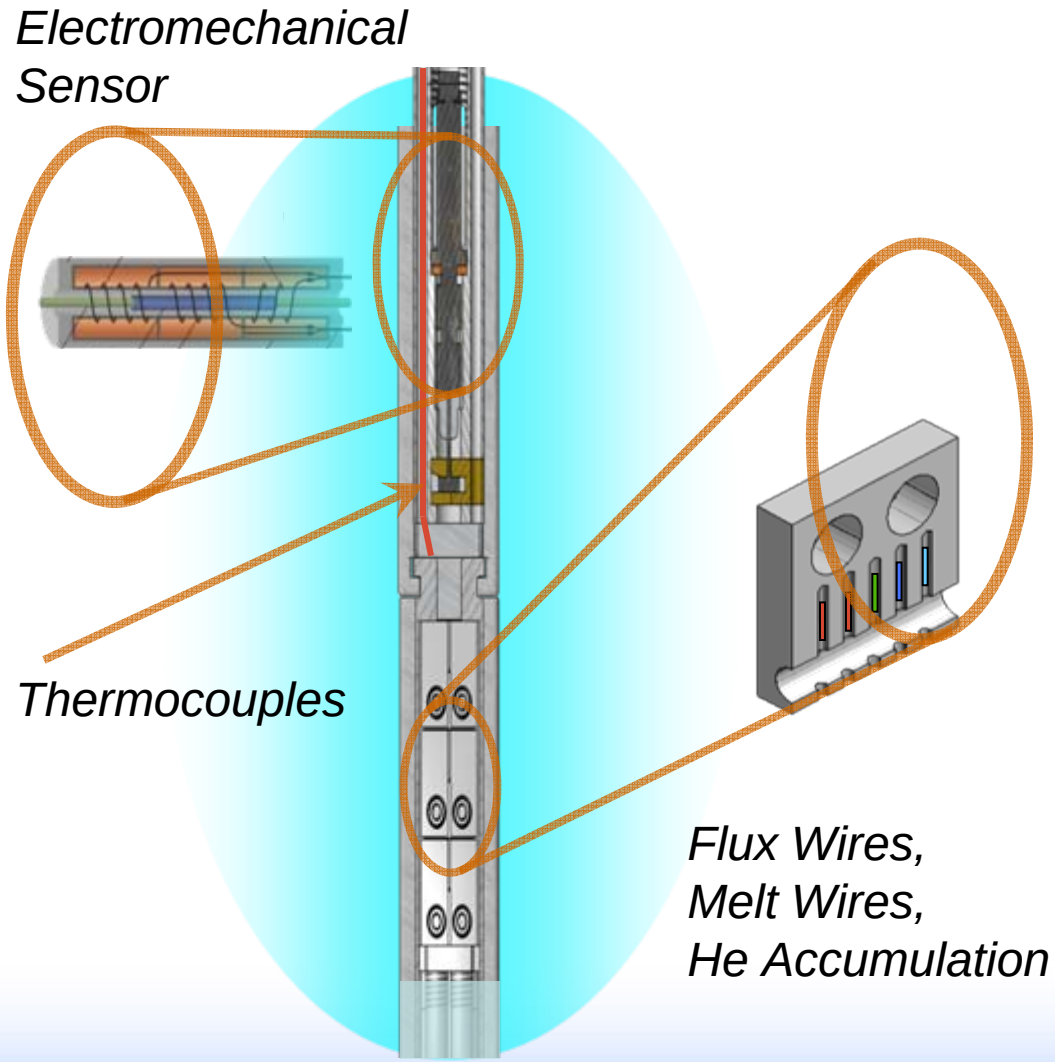


Test Train Instrument Concepts

- **LVDT (Linear Variable Differential Transformer) measures real time specimen growth or swelling**

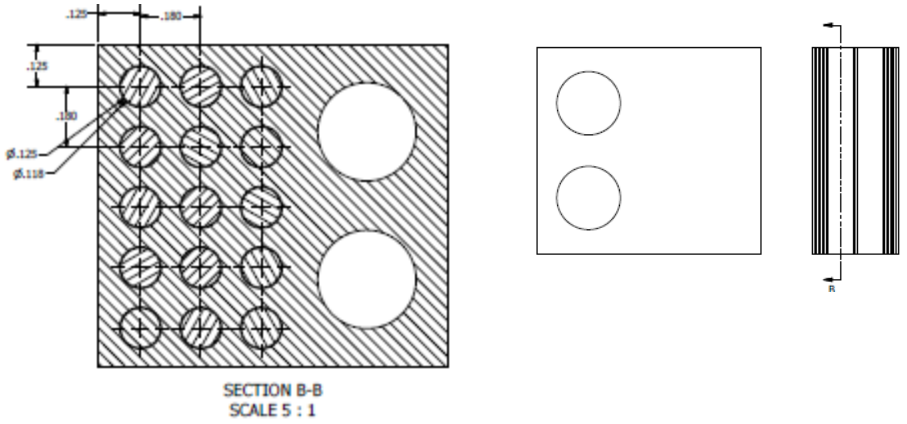
- **Thermocouple inserted into experiment inlet region**

- **Static flux, temperature, and He accumulation monitors can be placed adjacent to specimens**

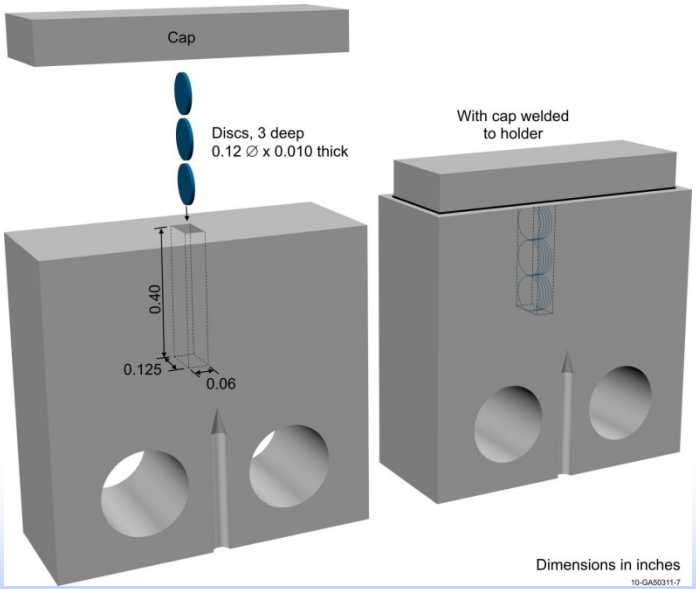


TEM and Met Discs

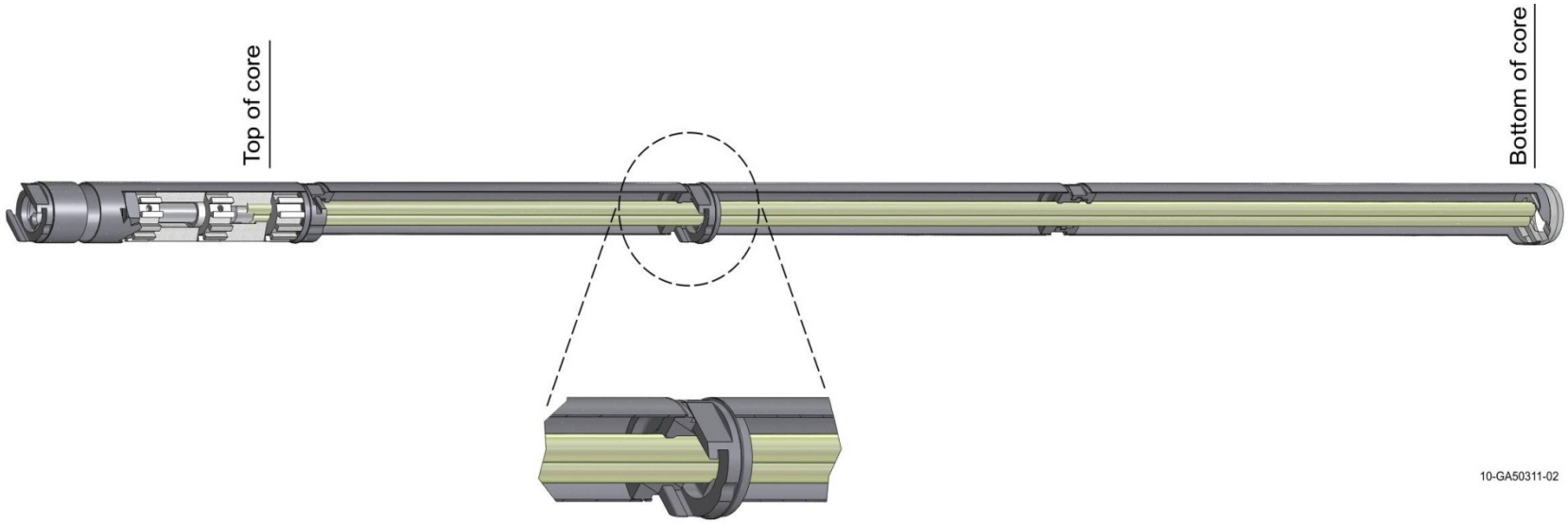
- **Specimen sheets or pre-machined samples placed in sheets and sandwiched in package next to CT specimens**



- **Alternately, discs can be placed in the same plane as the CT specimen notch**



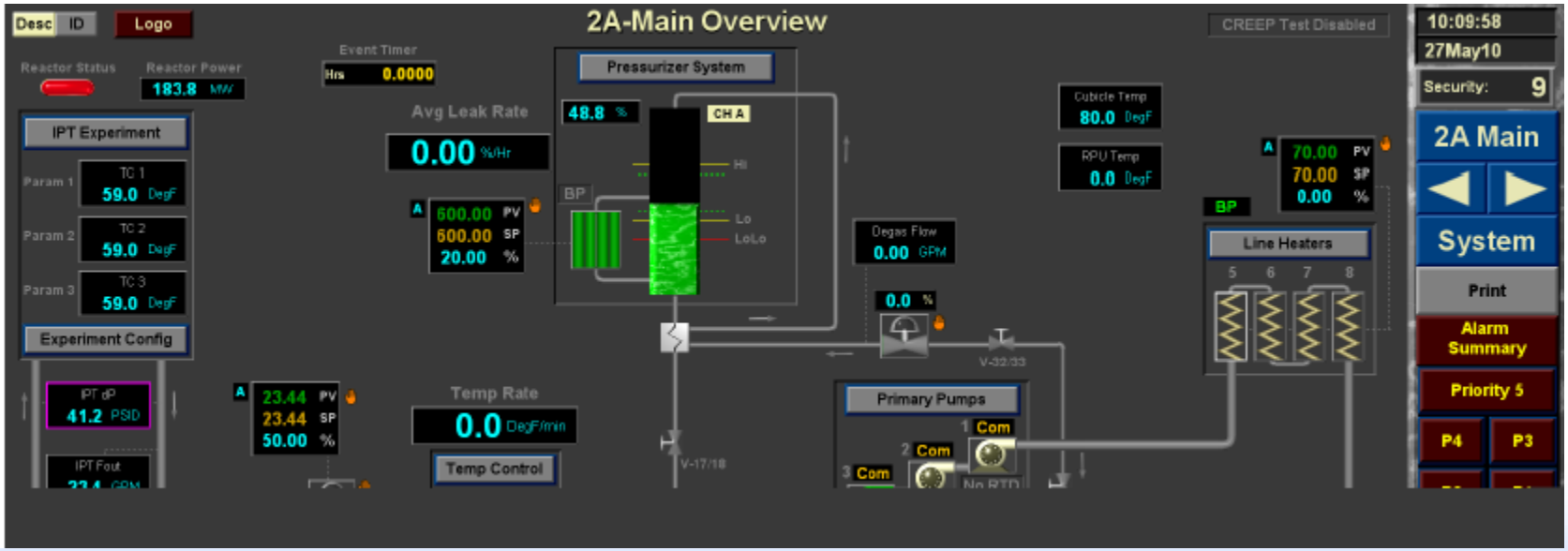
Example 2: LWR Sustainability SiC Ceramic Clad Fuel



LOOP CONTROLS & INSTRUMENTATION

Loop 2A Upgrades*

- Replaced Distributed Control System (DCS)
- Upgrading to provide monitoring and control (pressure, temperature, and flow)
- Planned: Data acquisition and monitoring with user internet access to unclassified data
- Screen example:



Idaho National Laboratory

* By ATR Design and Project Engineering

Experiment Support

- **Planned:**
  - **Neutron flux monitoring instrumentation (SPND and fission chamber interfaces)**
  - **High temperature thermocouples and monitoring interfaces (including ice point reference)**
  - **Thermal conductivity instrumentation (constant current sources, power and thermocouple monitoring interfaces)**
  - **Creep test/material expansion instrumentation (high accuracy, in core qualified LVDT systems)**
- **Proposed:**
  - **Ultrasonic based sensor**
  - **Fission gas measurement**
  - **Radio frequency (RF) sensor support**
  - **Fiber optic sensor**
- **Most test train sensors will be supplied by user**

Comments/Questions

- **In-Pile Tube**
- **Test Train**
  - **Experiment Options**
- **Planned/Proposed Instrumentation and Controls**