

Hot Cell System for Determining Fission Gas Retention in Metallic Fuels

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HOTLAB 2016

Karlsruhe
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10/5/2016

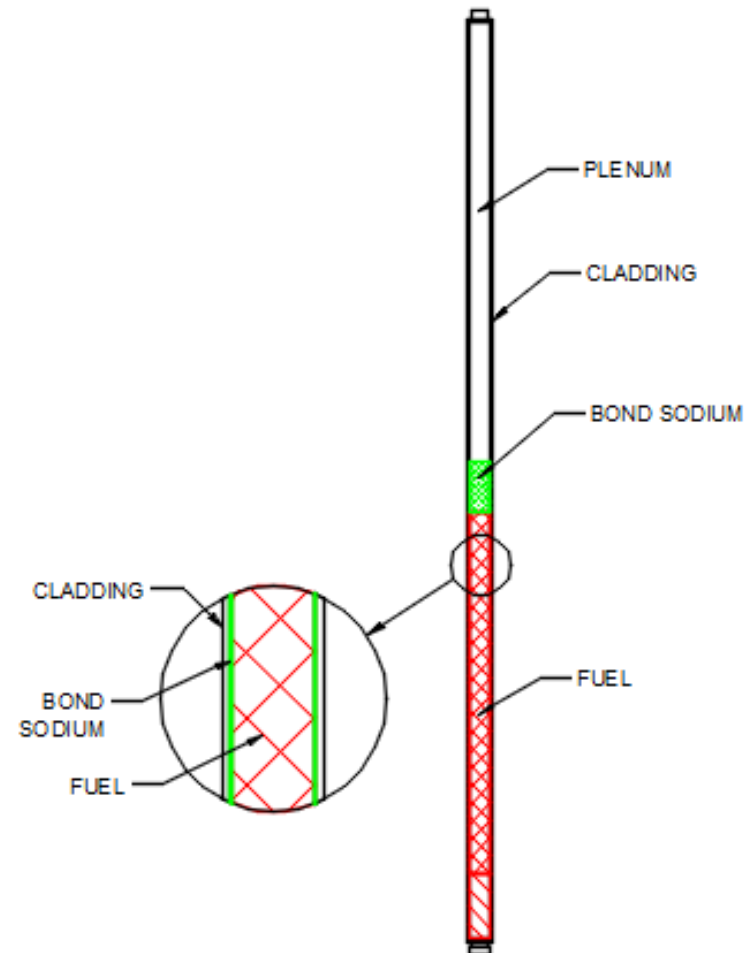


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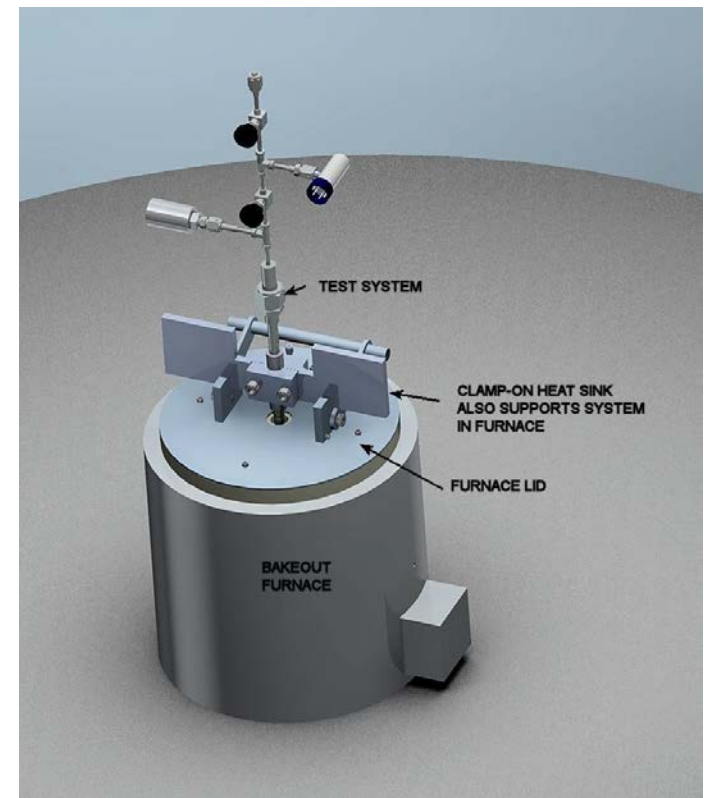
Background / Introduction

- **New sustainable and economic nuclear energy system is being developed which may use metallic fuel elements**
- **Greater understanding needed in the amount of fission gas that is retained in the fuel material**
- **Retained fission gas in the fuel material may influence the stress applied to the cladding wall by the fuel**
- **Significant amount of fission gas remains captured in the fuel**
- **Bond sodium may also retain/trap some fission gas once the fuel element cools and the sodium solidifies**



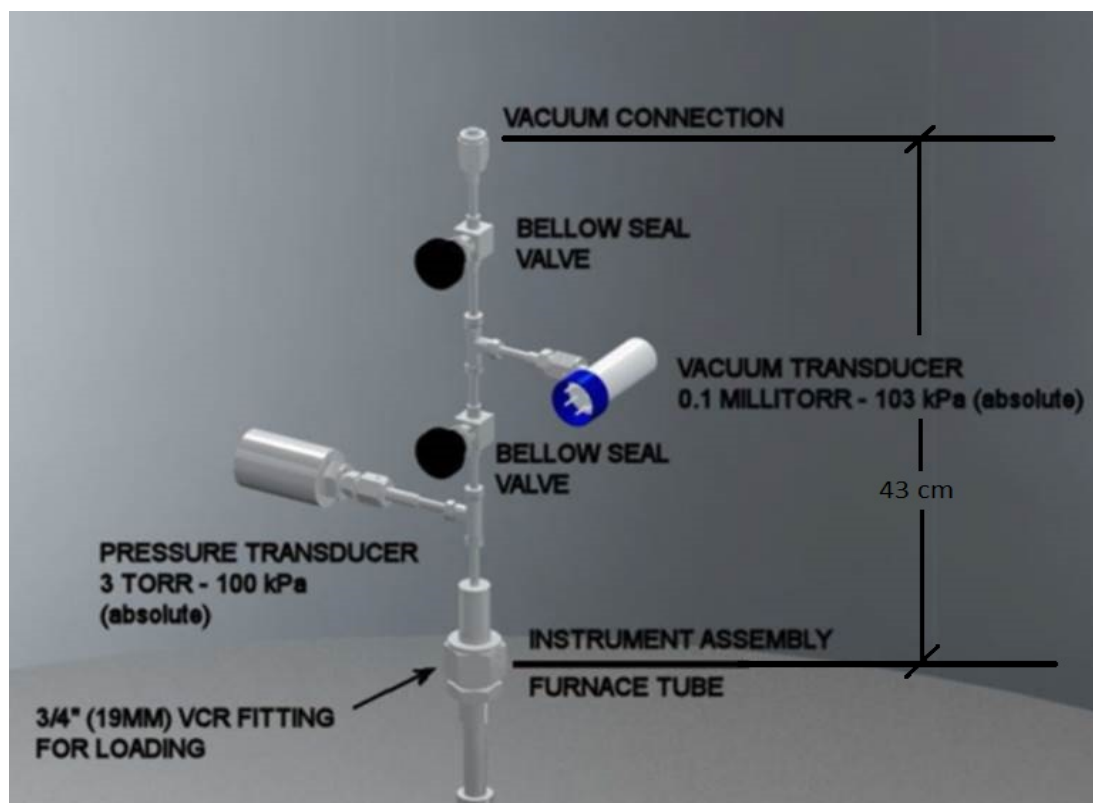
General System Description

- Designed to test small sodium bonded metallic fuel samples
 - Sample size: 6.85 mm OD x 24.5 mm long (in 4 segments)
- Collect and measure fission gas released from small metallic fuel samples
- Heat test samples to 1000°C
- Maximum Pressure: 100 kPa
- Minimum Pressure: vacuum
- Leak Rate: < 10 millitorr in 10 minutes
- Utilizes existing in-cell equipment:
 - Bakeout furnace
 - Vacuum Pump
 - Fission gas sampling and element volume determination system
- Main Components:
 - Instrument Assembly
 - Furnace Tube
 - Data Acquisition System



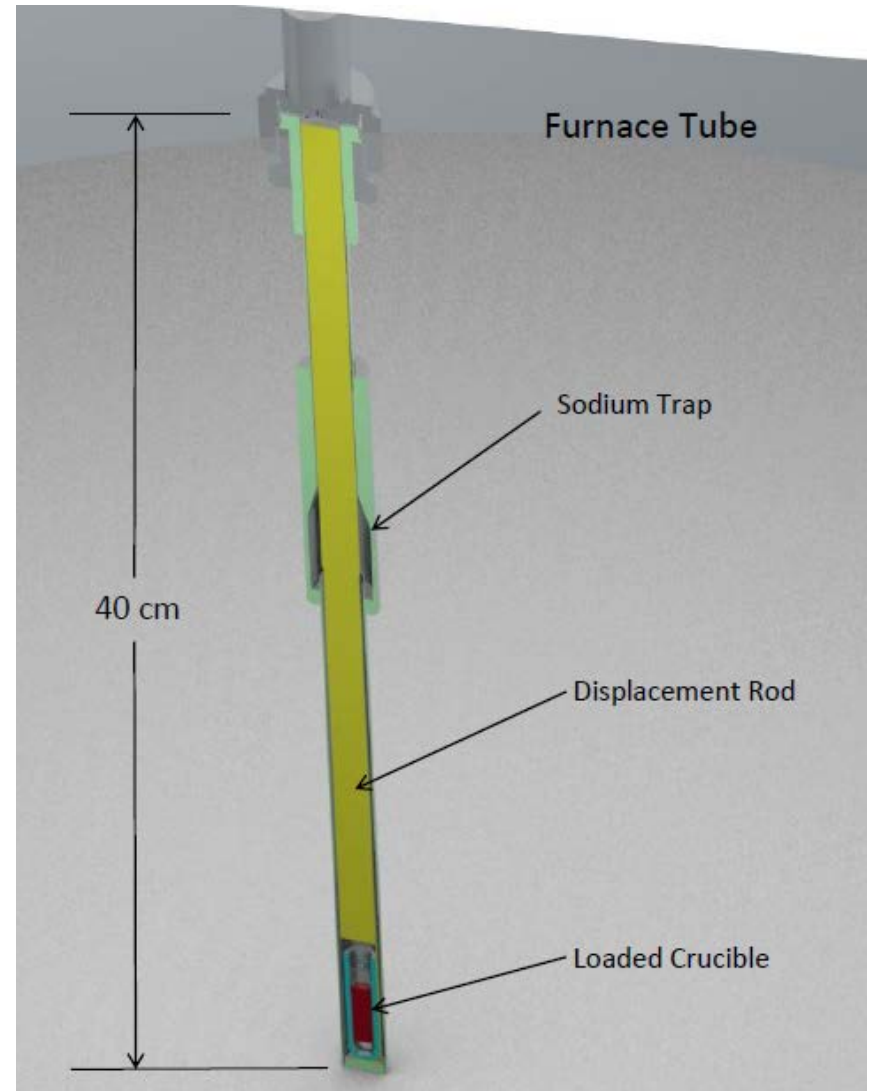
General System Description

- System installed in HFEF Main Argon Hot Cell
- Instrument Assembly
 - Vacuum Transducer
 - Used to verify system is leak tight
 - 0.1 millitorr – 103 kPa absolute
 - Pressure Transducer
 - Used to measure gas release from fuel samples
 - 3 Torr – 100 kPa absolute
 - Reuseable



General System Description

- **Furnace Tube**
 - House the crucible with fuel sample and iron powder
 - Displacement Rod
 - Sodium Trap



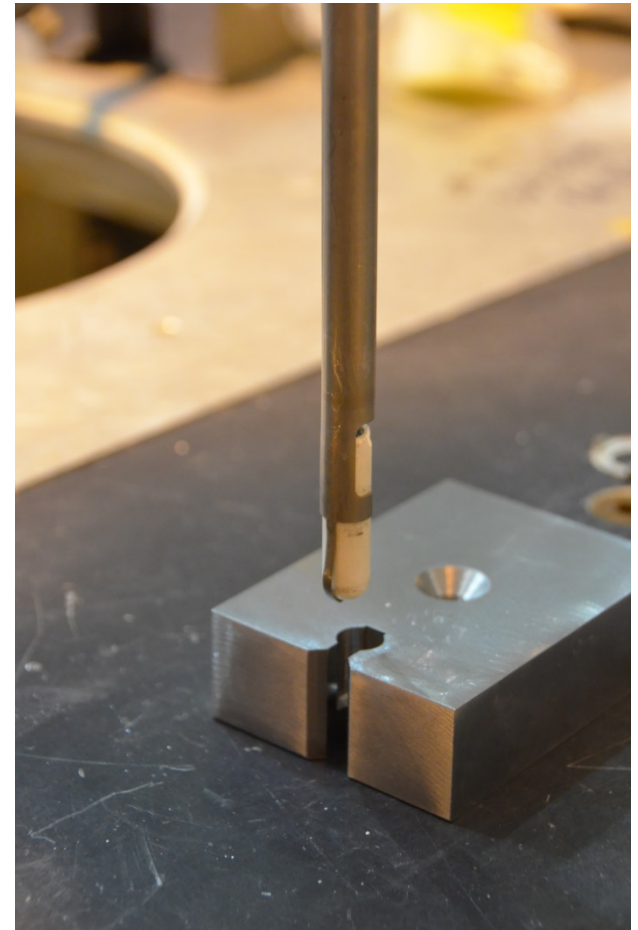
General System Description

- Data Acquisition System
 - Record vacuum, pressure, and temperature data



Pre-Test Development

- Investigated melting of U with iron or manganese powder at 1000°C
 - Post-test examination showed a eutectic formed and the surrogate fuel melted
 - Iron powder chosen for actual tests
- Prototype testing of retained fission gas apparatus
 - Investigated remote handling of surrogate fuel samples and iron powder loading into the crucible
 - Simulated operation of the system in a hot cell
 - Evacuated assembly
 - Heated to 1200°C



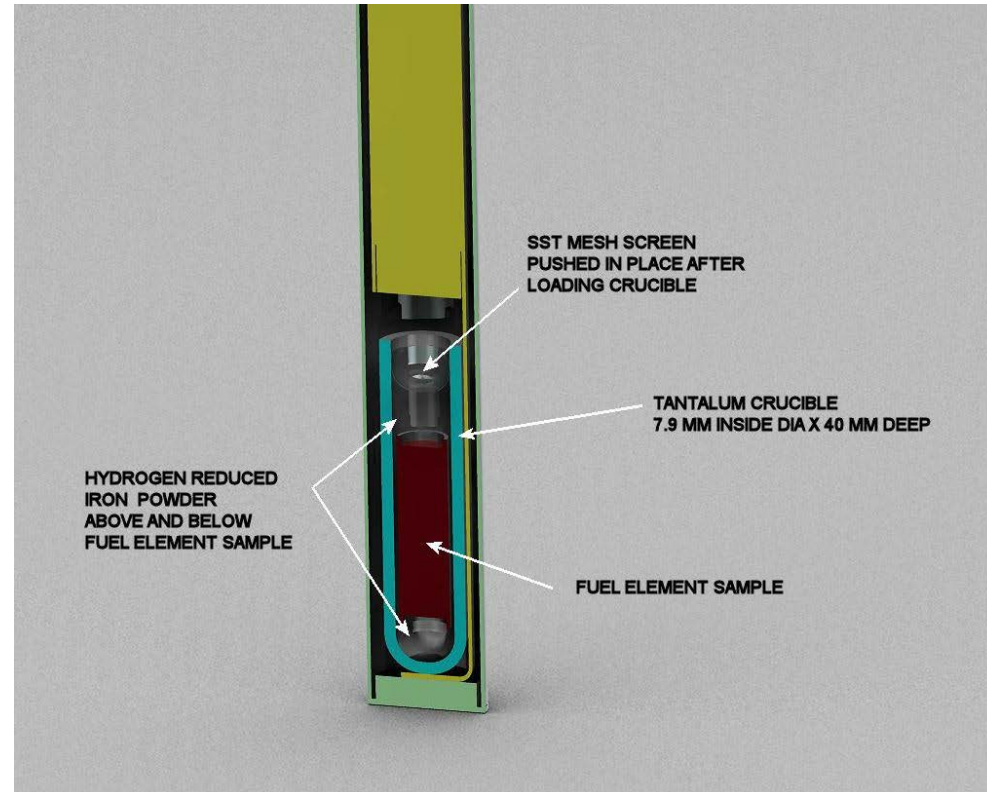
Pre-Test Development

- **Sodium trap performance testing**
 - **Loaded a zirconia crucible with sodium**
 - **Heated the assembled apparatus in excess of sodium boiling temperature**
 - **Cooled assembly**
 - **Disassembled assembly and allowed parts to sit in cell for the sodium to react and form NaOH**
 - **Used phenolphthalein solution to visually examine parts for sodium**
 - **Sodium trap performed as designed and no sodium in the instrument section**
 - **Zirconia crucible reacted with sodium, replaced with tantalum crucible**



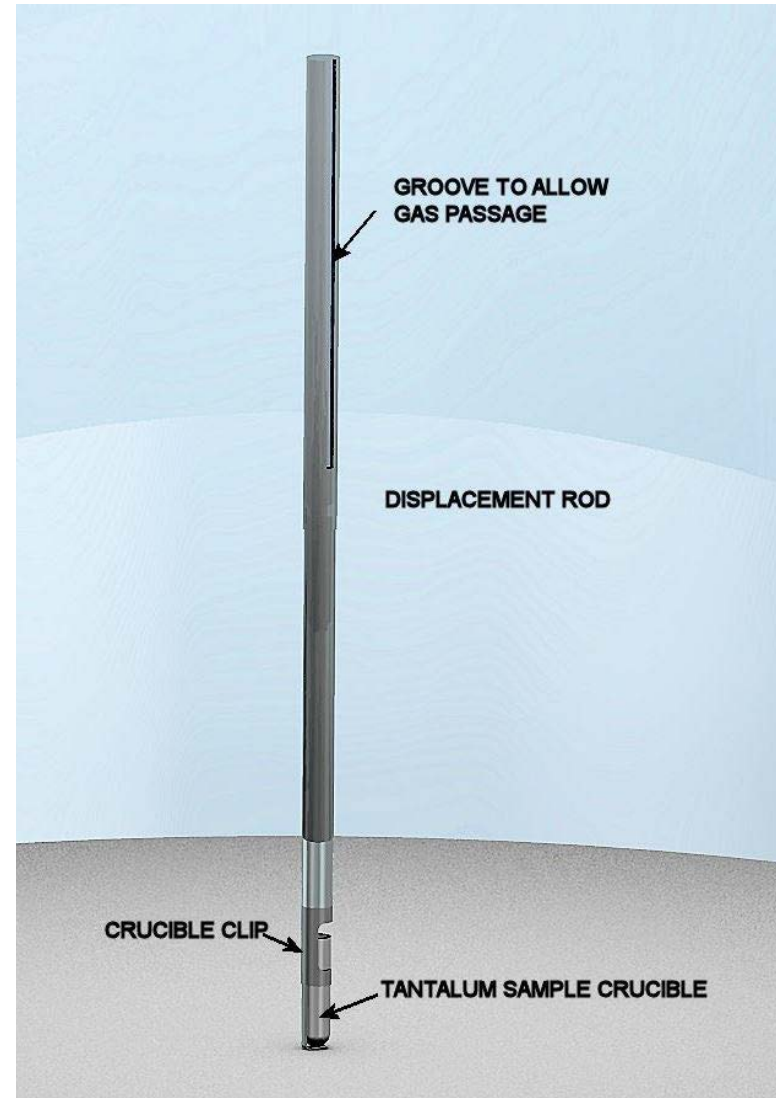
Test Procedure

- Fuel sample segments selected by experimenter based on position of fuel in element and burnup
- In-Cell Characterization of Fuel Sample Segments
 - Length
 - Weight
- Load Tantalum Crucible with fuel sample(s) and iron powder
- Install stainless steel mesh screen



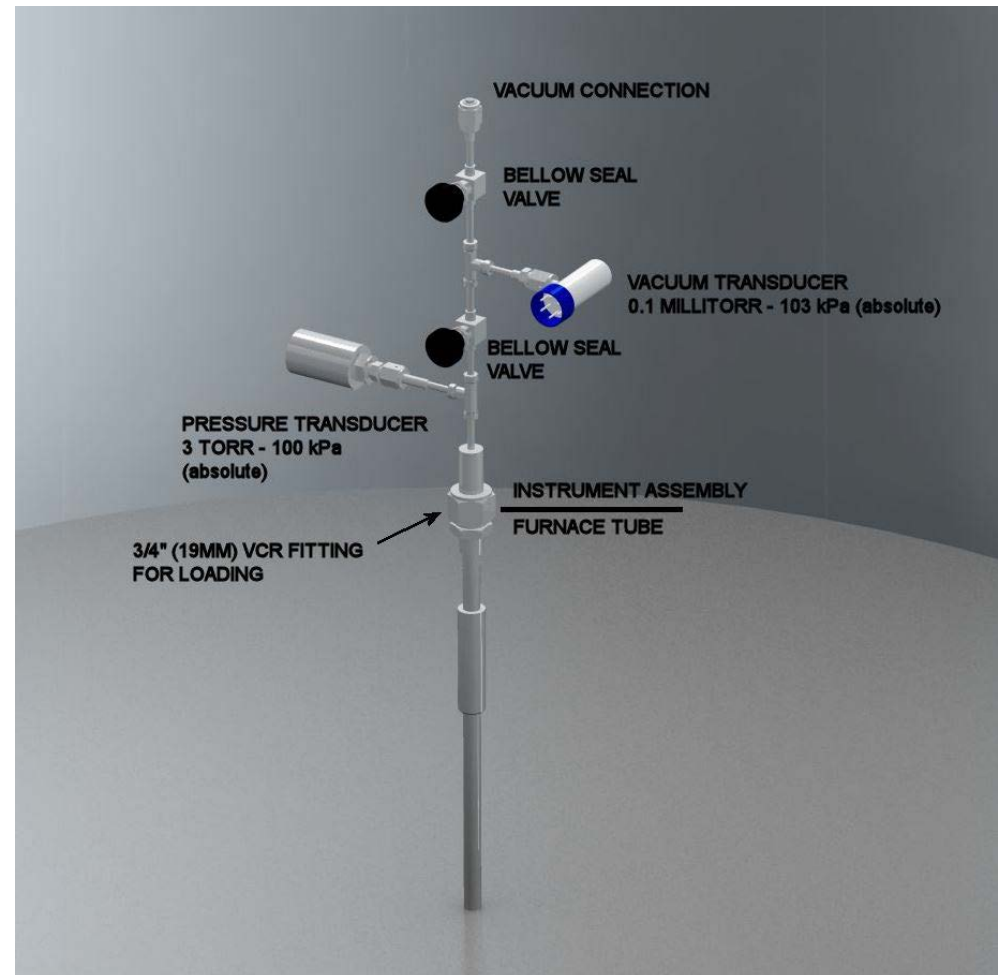
Test Procedure

- **Install crucible onto displacement rod with crucible**
- **Displacement rod**
 - Used to install the crucible into the furnace tube
 - Reduce the free volume inside the test apparatus



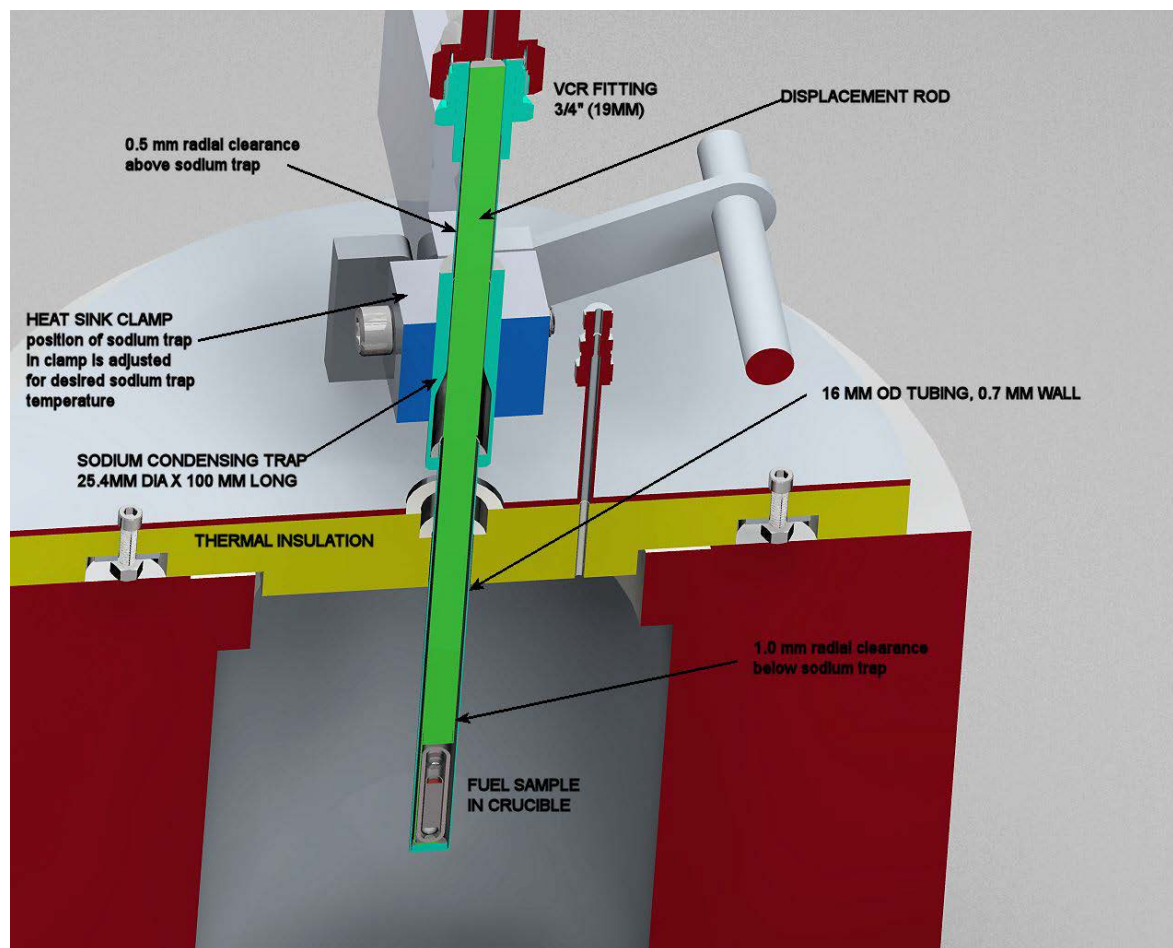
Test Procedure

- Install the displacement rod with crucible into the furnace tube
- Install the instrument assembly onto the furnace tube
- Connect instrumentation and vacuum pump to assembly
- Evacuate system < 50 millitorr
- Perform vacuum decay test
 - Leak rate < 10 millitorr in 10 minutes



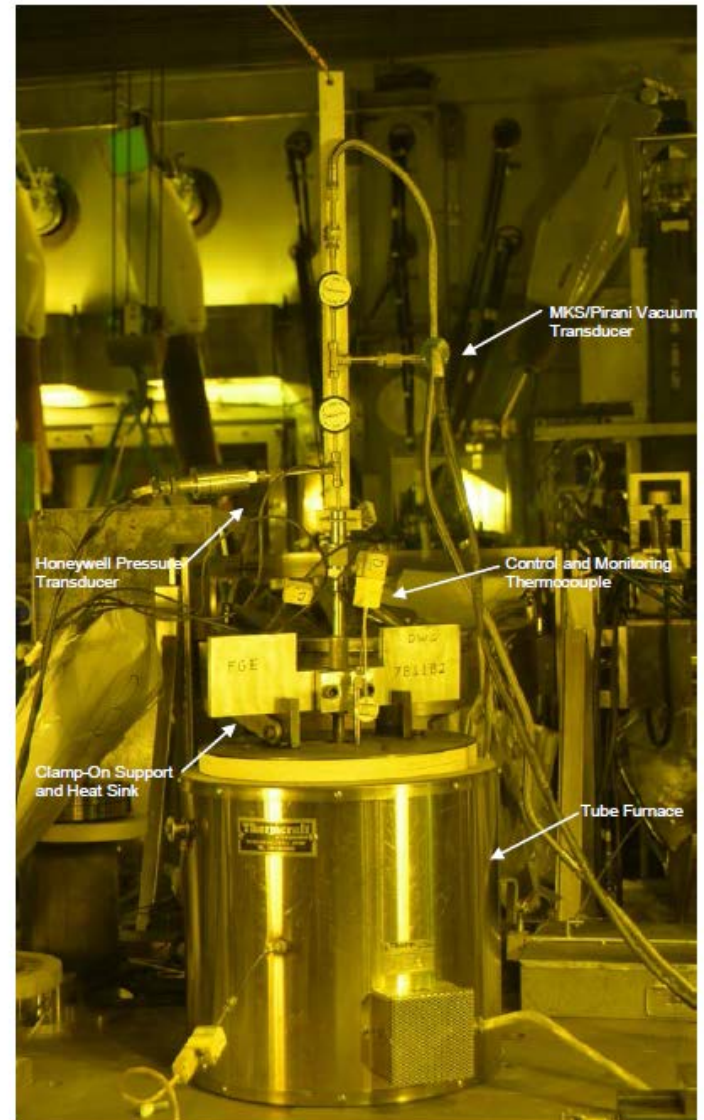
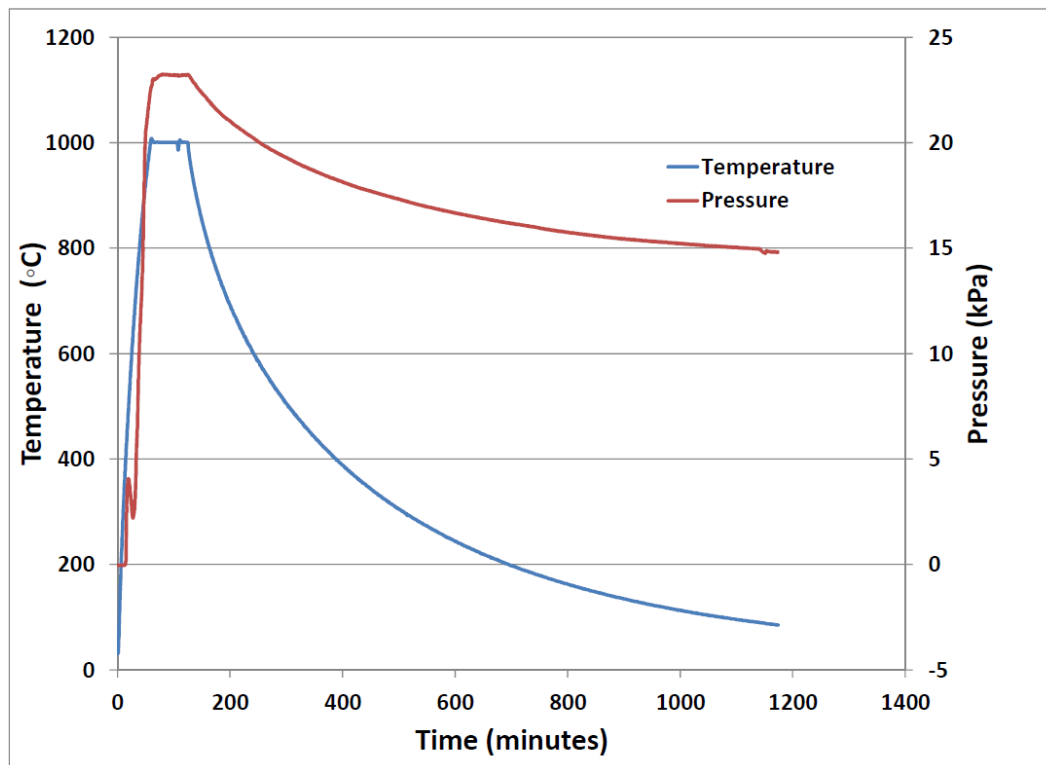
Test Procedure

- Install assembled test apparatus in support/heat sink



Test Procedure

- Verify system pressure < 100 millitorr
- Heat furnace to 1000°C and hold for 1 hour

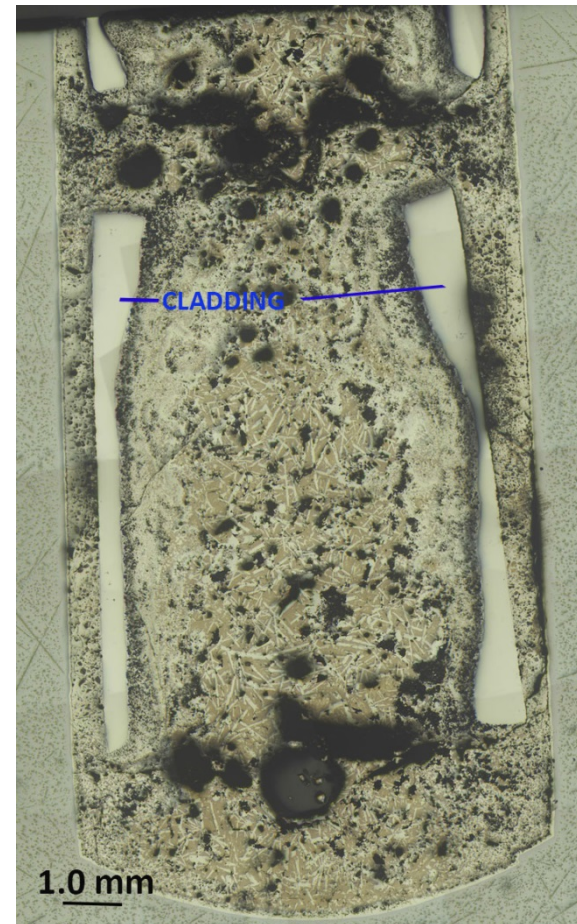


Test Procedure – Post Heat Up

- **Test Apparatus transferred to existing Gas Assay Sample and Recharge (GASR) System**
 - **Laser drill hole to retrieve gas sample**
 - **Measure volume of test assembly**
- **Total moles of gas released calculated**
 - **Pressure release measured during melting and final pressure measured again by GASR system**
 - **Test assembly volume measured by GASR**
- **Results for gas composition analysis confirm that a fission gas sample (Xe + Kr) recovered from fuel matrix**

Test Procedure

- **Metallography of melted fuel sample performed to verify complete melting occurred**



Summary

- **Retained Fission Gas System built to recover retained fission gases from metal fuel specimens**
- **System is located in an argon hot cell**
- **Remotely operated**
- **System has been operational since April 2016**
- **Five tests have successfully been performed**