Mechanistic Fuel Failure Examination System (MFFES)

MFFES

- Qualification of new fuel types requires that irradiated fuel assemblies be tested to destruction to evaluate the failure mechanisms as they relate to off normal reactor events.

- The Reduce Enrichment for Research and Test Reactors (RERTR) program is preparing for the qualification phase of fuel development of the U-xMo dispersion and monolithic fuel system. A furnace system is under development for placement in the main hot cell located in the Hot Fuels Examination Facility (HFEF) at the Idaho National Laboratory (INL). This following describes the furnace system and its capabilities. MFFES is currently in fabrication with projected installation in the HFEF hot cell in 2013.
Main Furnace

• High Vacuum
• Graphite Resistance Elements
• T Range 0-2000 °C
• Argon Sweep Gas
• Water Cooled
• 10X30.5 cm Heat Zone
• Clam Shell Access
• Light and Camera Ports.
Thermal Gradient Furnace

• Connects To Main Furnace
• Six Discreet Heat Zones
• Clam Shell Design
• Heat Zone 2.5X76 cm
• T Range 0-900 C.
Fission Gas System

- High Purity Germanium Detector
- Gas Collection Grab Samples
- Online Real-time Detection
Camera System

• 2 Cameras and 4 Lights Flanking Opposite Sides of Main Furnace
• Real-time Blister Formation Data.
Camera System Parameters

• Lights are adjustable in terms of position and brightness
• Camera has a modest focal distance range.
• Camera is analog black and white capturing ~1 frame/s.
• Maximum temperature for image capture ~550°C.
• Blister test will conclude at ~550°C.
Camera System Issue

- Camera and light ports mounted on door.
  - Camera stands have to be removed to open door.
  - Cameras must be repositioned for each blister anneal test.
- Continuous argon gas flow and monitoring for fission gas release during blister anneal.
- Temperature ramp rate to be determined.
- Can thermal cycle plate of desired.
In-Cell Detection System

- Flanks Thermal Gradient Furnace
- Position Optimization
- Adjustable Collimation
- Real-time Tube Deposition Data.
Test Train

Dispersion Plates:
- RERTR-11 (selected plates)
- RERTR-11A (selected plates)
- RERTR-X (U-Alx miniplates for baseline study)

Monolithic Plates:
- AFIP-4 (12 plates, 6 HIPped & 6 Friction Bonded)
- RERTR-12 (selected plates)
- RERTR-11A (selected plates)
- RERTR-13 (selected plates)
Experiment Approach
Blister Anneal

– All plates will be blister annealed with video capture of blister formation.
– Time and temperature will be recorded.
– Temperature will be increased stepwise.
– Hold time will be 20-30 minutes.
– Argon gas sweep to measure any fission product release.
Experiment Approach
Plate Melt

- Following blister anneal, plates will be placed in melt crucible.
- Temperature will be ramped or increased step-wise.
- Argon sweep gas will carry fission product past detection systems.
- Gradient furnace will capture volatilized fission product and plate inside of tube based on temperature.
- Fission gas will be measured and sampled for gas mass spectroscopy.
- Remaining material will be analyzed for burn-up analysis and remaining fission product inventory.
Experiment Approach
Plate Melt

– It is most likely that a stepped temperature approach will be applied (a steady ramp is possible at the discretion of the experimenter).
– This will be established based on known failure points for the fuel system.
– Test will continue until the last temperature step is reached plus ~25 °C.
– This temperature will be held until no more fission gases are being generated.
In Cell Layout
Lessons Learned

– HFEF hot cell window space is in very high demand. Only half a window was available for use.

– Fitting a rather large system in half a window has been challenging from a design perspective.

– We do not have optimal manipulator access as we are left of center in front of the window.

– Closure placement went through several iterations to optimize access.

– Finding room for all the peripheral measurement/data gathering equipment in-cell has been difficult. We had to give up a detector for the exit filters.
Lessons Learned-
What we did wrong

- We did not plan enough time for how long the design work would REALLY take, this more than tripled the cost of design. This also has impacted installation schedule.

- We did not anticipate the complexity of putting a large system in half a window and not being centered in front of the window (hence the escalation in design costs).

- Other issues are likely to surface in Mock-up in 2012 after system set up (but we fully expect everything to be perfect ;-).
Lessons Learned-
What we did right

– From the beginning of the design, we involved our technical staff from our hot cell mock-up area.

– We talked to other programs who installed similar systems to find out what they learned, what their mistakes were.

– We had design reviews for each component as well as whole system design reviews. We incorporated all comments.

– We conducted a factory qualification visit and as a result identified an heat sink issue BEFORE delivery of the furnace to INL. Manufacturer is fixing it now.