Outline

- Purpose for air/moisture-ingress testing
- Data to be collected
- System summary
- Schedule
- Status
- Non-radioactive development testing
Purpose of Testing in Air and Steam

- Safety testing of AGR fuel has only been under helium (FACS/CCCTF)
- Accident scenarios in HTGRs include depressurized conduction cooldown events:
  - Main coolant line break with air-ingress
  - Steam generator tube leak with moisture-ingress
- Fuel oxidation will occur when exposed to air or steam at high temperatures:
  - Compact matrix and particle OPyC layer oxidation
  - SiC generally resistant to but will slowly oxidize as well
- Small amounts of fission products accumulate in compact matrix during irradiation
- Oxidation of matrix and OPyC will mobilize fission products outside of the OPyC
- Exposed kernels (from as-fabricated defects or failures) vulnerable to hydrolysis
Goals of Air/Moisture Ingress Testing

• Test irradiated TRISO fuels in oxidizing environments representative of air and moisture ingress accidents in HTGRs

• Measure fission product releases as a function of time

• Relate fission product releases and release rates to fuel irradiation history, test conditions, and extent of fuel oxidation

• Use collected data for:
  ▪ Fuel qualification and licensing
  ▪ Input to and comparisons with predictive models and simulations
  ▪ Reactor accident source term analysis
Data Collection

• Fission product releases as a function of test time
  ▪ Fission product gases:
    • Kr-85 (indicates failure of all three TRISO layers)
    • Xe-133 (could be measured from tests following re-irradiation)
  ▪ Never before done in air/moisture: condensable fission products
    • Ag-110m
    • Cs-134/137 (indicates SiC layer failure)
    • Eu-154/155
    • I-131 (measured from re-irradiated samples)
    • Sr-90

• Extent of sample oxidation as a function of time
• Irradiated fuel compacts, fuel bodies, fuel pebbles, loose particles, irradiated graphite bearing fission products
## Planned Range of Test Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
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<tbody>
<tr>
<td>Total test pressure (kPa)</td>
<td>(~85) (ambient)</td>
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<tr>
<td>Air Partial Pressures (kPa)</td>
<td>0.1 to 85</td>
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<tr>
<td>Moisture Partial Pressures (kPa)</td>
<td>0.1 to 85</td>
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<tr>
<td>Temperature Range (°C)</td>
<td>(T_{\text{min}} &lt; 800, T_{\text{max}} = 1650)</td>
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<td>Flow velocity at the sample (m/s)</td>
<td>0.1 to 0.2</td>
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<td>Test durations (hr.)</td>
<td>100 +</td>
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Notes:
- Higher/lower partial pressures possible with changes to equipment
- Higher temperatures not possible
- Lower temperatures possible, but with reduced furnace element life
Installation at Fuel Conditioning Facility (FCF)

Air Cell at FCF
Equipment Locations at FCF

Main Floor Window A3

Basement Beneath A3
Simplified Overall Schedule and Milestones

<table>
<thead>
<tr>
<th>Event Description</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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<tr>
<td>Conceptual Design</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
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<tr>
<td>Benchtop testing</td>
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<td>60% design review for in-cell system</td>
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<tr>
<td>Final design</td>
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<td>FCF facility modifications</td>
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<tr>
<td>Equipment procurement and fabrication</td>
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<tr>
<td>Phase 1 and Phase 2 qual in NHL/mockup</td>
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<tr>
<td>Install equipment in FCF air cell</td>
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<tr>
<td>Feedthrough(s) installation</td>
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<tr>
<td>Phase 3 qualifications</td>
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<tr>
<td>Approval for hot operations</td>
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<tr>
<td>Initiate air/moisture ingress safety test</td>
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**FY18 Milestones:**
- Level 2: Complete construction of bench top air/moisture ingress furnace gas supply, exhaust, and gas analysis, and initiate testing in air and steam environments – **Completed on time**
- Level 2: Complete final design of air/moisture ingress furnace – Due: 7/6/2018, **design reviews in progress and on schedule**
- Level 3: Complete FCF air cell waste management to support radiation background measurements to verify design assumptions of gamma detectors – **Completed on time**
Level 2 Milestone to Complete Final Design Review: Due 7/6/2018, On Schedule

Design review divided into 4 pieces:

1. Out-of-cell equipment (flow meters/controllers, piping, valves, water supply, condensate collection, fission gas monitoring equipment, etc.)
   - Completed design review on 1/8/2018
   - Completed and released piping and instrumentation diagrams (P&ID) and drawings for other components (e.g. condenser, skids, fission gas monitoring system traps, etc.)

2. Cell wall feedthroughs
   1. Thermal/shielding/seismic analyses checked drafts scheduled for 5/3/2018
   2. Final feedthrough design review scheduled for 5/14/2018

3. In-cell equipment (furnace, tables, handling fixtures, gamma detectors, etc.): final design review scheduled for 5/23/2018

4. Electrical, instrumentation and control, data collection: final design review scheduled for 6/14/2018
Out-of-cell System Design

- Completed and released Piping and Instrumentation Diagrams (P&ID)

NOTE: These three diagrams are just a small excerpt from the main P&ID, which is 47 pages.
• P&ID includes equipment list, part numbers, and specifications
• Most material/equipment listed has been ordered and is being assembled for Phase I testing
Feedthrough Design

- Completed feedthrough functional and operational requirements
- Drawings completed will be released after final design review
- Drafting engineering calculation and analysis reports (ECARs) by end of May:
  - Thermal
  - Seismic
  - Shielding
- Cell waste management for L3 Milestone Completed
- General area dose rates are 4Rem/hr, 5 times lower than assumed for design
- Smears show <1 µCi Cs
In-Cell Design and Related Work (continued)

- 3D models and drawings have been produced and are being refined
In-Cell Design and Related Work (continued)

- In the process of procuring furnace
- Aiming to ship to INL around mid-July 2018
In-Cell Design and Related Work (continued)

- Instrumentation and control/human-machine-interfaces/electrical diagrams
- Operational flow charts/recipes being developed
In-Cell Design and Related Work (continued)

- FCF facility-required work:
  - Criticality Safety Evaluation (CSE) in-review
  - Draft hazard categorization in review
  - Air Permitting Applicability Determination drafted
  - Began drafting DSA revision for annual update
Benchtop Testing of Systems/Components

- Air and steam atmospheres
- Heat trace
- Residual gas analysis for oxidation of carbon
- Testing filter for particulate trapping and I-131
- Tube flanges
- Tube-within-a-tube design
- Sample loading/unloading
- Temperature measurements within and along tube
- Distribution of stable (non-rad) Ag, Cs, Eu, Sr, I within system
Future Work

• Remainder of FY18
  ▪ Complete final design review
  ▪ Continue procurement of most out-of-cell equipment
  ▪ Continue procurement of some in-cell equipment (furnace, gamma detectors, etc.)
  ▪ Continue benchtop development testing

• FY19
  ▪ Begin facility modifications (feedthrough installation etc.)
  ▪ Start Phase I and Phase II qualifications
  ▪ Begin installing equipment in FCF air cell
Questions and Discussion

<table>
<thead>
<tr>
<th>John Stempien</th>
<th>ART INL TRISO PIE Lead</th>
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</thead>
<tbody>
<tr>
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<td>Phone (208) 526-8410</td>
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