Multiphysics Pebble-Bed Reactor Control Rod Withdrawal Study

RESULTS PRESENTED ARE PRELIMINARY AND SUBJECT TO CHANGE

DOE ART Gas-Cooled Reactor (GCR) Review Meeting
Virtual Meeting
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Content

• Purpose of the Study
• Workflow
• Gas-Cooled PBR Control Rod Withdrawal
• Fluoride-Cooled PBR Control Rod Withdrawal
• Future Work
Objectives

• Study Control Rod Withdrawal (CRW) and Ejection (CRE) events in Pebble Bed Reactors (PBR)
• Develop models that can predict how much of the core exceeds a given temperature limit and for how long.
• Compare gas- and fluoride cooled PBRs
• Perform a sensitivity analysis
**Cases to be considered**

<table>
<thead>
<tr>
<th>Event</th>
<th>Number of CRs</th>
<th>Initial State</th>
<th>CR Speed (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Rod Withdrawal</td>
<td>All</td>
<td>Full power</td>
<td>1</td>
</tr>
<tr>
<td>Control Rod Withdrawal</td>
<td>All</td>
<td>Cold zero power</td>
<td>1</td>
</tr>
<tr>
<td>Control Rod Ejection</td>
<td>1</td>
<td>Full power</td>
<td>10,000</td>
</tr>
<tr>
<td>Control Rod Ejection</td>
<td>1</td>
<td>Cold zero power</td>
<td>10,000</td>
</tr>
</tbody>
</table>
Workflow

1. Cross-section generation
2. Griffin-Pronghorn equilibrium core calculation
3. CRW/CRE Griffin-Pronghorn transient simulation
Advantages of model vs Point Kinetics

• Griffin-Pronghorn 2-D RZ multiphysics model can give information regarding:
  − How much of the core sees a temperature above a given limit?
  − For how long does it stay above that limit?
  − What is the heating rate of the fuel in that region?

• Less conservatism can enable a more competitive design
Gas-Cooled PBR Control Rod Withdrawal

- CR withdrawn at 1 cm/s
- Most of the reactivity added in the first minute
- Power peaks when reactivity insertion rate matches negative feedback rate from core heating
- Eventually stabilizes at a higher power
- Maximum fuel temperature much lower than fuel limits (~1900K)
Sensitivity Analysis (ongoing work)

- Parameters to be perturbed:
  - Reactivity insertion (move CR position)
  - Reactivity coefficients (potentially via volume fractions in each burnup group and cross-sections)
  - Thermal properties
  - Kinetics parameters (CRE only)
Fluoride-Cooled PBR Model

- Very similar model to gas-cooled PBR
- 2-D RZ Griffin model
- 2-D RZ Pronghorn model
- 1-D spherical Pronghorn TRISO models
- Control Rods modeled as “gray curtain”
- Additional feedback from fluid density
- Fluidic diode to allow onset of natural convection

Fluoride-Cooled PBR Control Rod Withdrawal

• Much stronger temperature feedback due to FLiBe density changes
• Power/temperature stabilize above nominal conditions
• But no overshoot observed
Conclusions & Ongoing Work

- Gas- and Fluoride-Cooled PBR 2D R-Z multiphysics models developed
- Preliminary CRW simulations performed for hot and cold conditions
- Ability to determine how much of the core exceeds temperature limits and for how long
- Ongoing Sensitivity Analysis work
Questions?