Calculation of Spent Fuel Pool Time-to-Boil using Polaris/ORIGAMI

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Overview

• Goal: calculate time-to-boil (TTB) for a Spent Fuel Pool (SFP)
  – TTB is important for SFP management
  – Represents the amount of time available to address loss of forced cooling

• Calculate and compare TTB for two cases using SCALE:
  – SFP containing representative LEU fuel ($\leq 5 \text{ wt } \%$)
  – SFP containing representative LEU+ fuel ($5 - 8 \text{ wt } \%$)
  – Approximately 2300 fuel assemblies in the SFP for each case
Methodology

$$\tau_{boil} = \frac{C}{Q_{GEN}}(212 \, ^\circ F - T)$$

- $C$ is the SFP water thermal capacity (BTU/°F)
- $Q_{GEN}$ is the heat generation rate in the SFP (BTU/h)
- $T$ is the SFP bulk water temperature (°F)
- $\tau_{boil}$ is the time-to-boil (h)

- Time-to-boil requires decay heat of SFP
  - Water properties are known/assumed
  - SCALE is used to calculate Qgen term:
    - Depletion calculations performed using Polaris
    - Discharge/decay calculations performed using ORIGAMI
Methodology (cont.)

• For LEU:
  - Decay heat is taken as sum of:
    • $(1 + 1/3)$ times discharge core decay heat (per NRC request), and
    • Decay heat of representative fuel already in the SFP
      – Data for representative fuel taken from UNF-ST&DARDS database
  - Depletion has been previously performed using TRITON to generate ORIGEN libraries for use with ORIGAMI
  - ORIGAMI calculations are run for core and SFP assemblies
Methodology (cont.)

• For LEU+:
  – Two cases are analyzed:
    1. \((1 + 1/3)\) LEU+ core + representative LEU fuel in SFP (represents first LEU+ discharge core)
    2. \((1 + 1/3)\) LEU+ core + representative LEU+ fuel in SFP (represents future LEU+ core)
  – To calculate decay heat for representative LEU+ SFP:
    • Start with representative LEU SFP assembly parameters
    • Multiply all burnups by a scaling factor of 1.35
    • This represents the approximate factor of \(75 \text{ GWd/MTU divided by } 55 \text{ GWd/MTU}\) (LEU+ burnup divided by LEU burnup)
    • Enrichment and other parameters are not changed
  – Run Polaris to generate ORIGEN libraries for LEU+ core and representative LEU+ fuel in SFP
  – Run ORIGAMI to generate decay heat
Methodology – Discharge Cores

- LEU/LEU+ discharge cores are grouped to minimize calculations required. For each core:
  - Assemblies are sorted into four groups based on enrichment, absorber content, and location
  - Polaris depletion calculation is performed for each assembly over a range of burnups
  - Average burnup is calculated for each group
  - A single ORIGAMI discharge calculation is performed for each group
    - Group-wise enrichment, MTU, and average burnup are used
    - 100 hours is assumed between reactor shutdown and fuel being loaded into the SFP

![LEU+ Discharge Core Exposure Map (Left) and Enrichment Map (Right).]
Time-to-Boil Results

- Time-to-boil is calculated for:
  - 1 + 1/3 LEU core + representative LEU fuel in SFP
  - 1 + 1/3 LEU+ core + representative LEU fuel in SFP (represents first LEU+ discharge core)
  - 1 + 1/3 LEU+ core + representative LEU+ fuel in SFP

<table>
<thead>
<tr>
<th></th>
<th>LEU Core and LEU SFP</th>
<th>LEU+ Core and LEU+ SFP</th>
<th>LEU+ Core and LEU SFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qgen, SFP (Btu/hr)</td>
<td>6.61E+06</td>
<td>9.99E+06</td>
<td>6.61E+06</td>
</tr>
<tr>
<td>Qgen, Total (Btu/hr)</td>
<td>6.77E+07</td>
<td>7.28E+07</td>
<td>6.94E+07</td>
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<tr>
<td>TTB (hr)</td>
<td>4.58</td>
<td>4.26</td>
<td>4.46</td>
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Time-to-Boil Conclusions

• Impact of LEU+ core on time-to-boil is very small
  – At such low cooling times, the impact of increased decay heat is not significant
  – Decay heat of SFP assemblies is small compared to discharge core decay heat