PWR Fuel Performance Update

George Borum
Framatome/NRC Fuel Performance Meeting
September 14, 2021
AGENDA

- Objectives
- Framatome PWR Fuel Operating Experience
  - Status of Product Implementation
  - Fuel Reliability Statistics
- Status of Framatome PWR Fuel Failures and Investigations
  - Cause of Failure Examinations
- Poolside Surveillance Results and Plans
  - Recent PWR Poolside Surveillance Campaigns
  - Upcoming PWR Poolside Surveillance Campaigns
- EATF PROtect Summary
- Summary / Conclusions
Objectives

- Summarize key aspects of current PWR fuel product features
- Provide a status update of the overall performance of Framatome's PWR designs
- Provide an updated status of GAIA and AGORA lead fuel programs
- Provide an overview of PWR fuel examinations and results of recent surveillance campaigns
- Provide an overview of anticipated fuel examinations
- Provide an overview of the current EATF projects
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HTP Fuel - Proven Features

- Reconstitutable Upper Nozzle/End Fitting / Tie Plate
- $M_5^{Framatome}$ Fuel Rod Cladding
  - Low oxidation compared to Zry-4
    - Low hydrogen pick up
- HTP Spacer Grid
  - Exceptional GTRF performance
- HMP Lower Grid
- FUELGUARD Bottom Nozzle/End Fitting / Tie Plate
Framatome PWR Reloads
B&W Plants

Mark-B HTP has effectively eliminated past performance issues associated with GTRF, growth and fuel assembly distortion
First domestic GAIA Reload was loaded in the spring 2021
HTP Irradiation Experience

Nearly 25,000 HTP assemblies irradiated in 51 reactors worldwide
- Arrays from 14x14 to 18x18
- Operating in a variety of reactor platforms
  - B&W, CE, Framatome, Siemens, and Westinghouse
GAIA Fuel Assemblies
Key Design Features & Irradiation Experience
AGORA 5AI Lead Fuel Assemblies
Key Design Features & Irradiation Experience
Framatome PWR Fuel Performance Summary
United States

- All PWRs with Framatome fuel in-core operating defect free in US
- HTP continues to demonstrate improved performance over predecessor designs
- 4 EATF GAIA Assemblies are completing their 2nd cycle of irradiation in March 2022
- First GAIA reload in the United States began irradiation in May 2021
- 4 AGORA 5AI assemblies completed a 3rd cycle of operation with no performance concerns
PWR Fuel Failure Mechanisms (United States 2017-Current)
PWR Fuel Failure Mechanisms
Focus on Debris Failure Trends, Since 2012 - PWR
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Recent US PWR Failed Fuel Exams

2020 Cause-of-Failure Exams

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<tr>
<th>Reactor</th>
<th>Cycle</th>
<th>Assembly</th>
<th>Fuel Product</th>
<th># Rods</th>
<th>Exam</th>
<th>Cause</th>
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2021 Cause-of-Failure Exams

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Domestic PWR Poolside Surveillances
GAIA Fuel Assemblies with EATF PROtect Fuel Rods

Good overall performance of lead assemblies confirmed
GAIA Fuel Assemblies with EATF PROtect Fuel Rods
Visual Inspection
GAIA Fuel Assemblies with EATF PROtect Fuel Rods
Visual Inspections
GAIA Fuel Assemblies with EATF PROtect Fuel Rods
Visual Inspections
AGORA 5Al Lead Assemblies
AGORA 5AI Lead Assemblies
Visual Inspection
AGORA 5Al Lead Assemblies
Fuel Assembly Growth
AGORA 5Al Lead Assemblies
Guide Tube Oxide and ID Wear
Anticipated PWR Fuel Surveillance Campaigns through 2025
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EATF PROtect Summary
GAIA Fuel Assemblies with EATF PROtect Fuel Rods
Vogtle-2
ANO-1 EATF PROtect Fuel Rods
ANO-1 EATF PROtect Fuel Rods
Calvert Cliffs EATF PROtect Fuel Assembly
Summary/Conclusions

- HTP and GAIA continue to demonstrate improved performance over predecessor designs.
- All US PWR customers have transitioned to advanced cladding ($M5_{\text{Framatome}}$) with low oxidation, growth, and hydrogen pickup.
- Framatome is successfully implementing next generation PWR products (via LFA programs) incorporating proven and effective design features.
- Framatome is committed to resolving conditions adverse to fuel reliability.
- Framatome's active PIE program continues to validate the successful performance of Framatome PWR fuel products.

Framatome is committed to proactively addressing conditions adverse to fuel reliability and supporting our customers with leak free performance.
### Acronyms/Nomenclature

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANO</td>
<td>Arkansas Nuclear One</td>
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<tr>
<td>B&amp;W</td>
<td>Babcock and Wilcox</td>
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<tr>
<td>CE</td>
<td>Combustion Engineering</td>
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<td>DNB</td>
<td>Departure from Nucleate Boiling</td>
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<td>EATF</td>
<td>Enhanced Accident Tolerant Fuel</td>
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<td>EOC</td>
<td>End of Cycle</td>
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<td>FA</td>
<td>Fuel Assembly</td>
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<tr>
<td>FR</td>
<td>Fuel Rod</td>
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<td>GTRF</td>
<td>Grid-to-Rod Fretting</td>
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<tr>
<td>ID</td>
<td>Inside Diameter</td>
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<tr>
<td>IFM</td>
<td>Intermediate Flow Mixer</td>
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<td>IGM</td>
<td>Intermediate GAIA Mixer</td>
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<td>Lead Fuel Assembly</td>
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<td>Loss of Coolant Accident</td>
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<td>Nuclear Regulatory Commission</td>
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<td>Post Irradiation Examination</td>
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<td>Rod Control Cluster Assembly</td>
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<td>TMI</td>
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<tr>
<td>US</td>
<td>United States</td>
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<tr>
<td>W</td>
<td>Westinghouse</td>
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<tr>
<td>Zry-4</td>
<td>Zircaloy-4 alloy</td>
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Trademarks

The alloy $M_{\text{Framatome}}$ is named "M5" in this document.

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