Fuel Reliability Guidelines

EPRI Fuel Reliability Program
Overview

• Support industry effort to achieve zero fuel failures by 2010

• Five guidelines to be issued by mid-2008
  – Fuel Surveillance and Inspection
  – Pressurized Water Reactor Fuel Cladding Corrosion and Crud
  – Boiling Water Reactor Fuel Cladding Corrosion and Crud
  – Grid-to-Rod Fretting
  – Pellet Cladding Interaction

• Broad and global involvement by nuclear utilities and nuclear fuel manufacturers

• Phased implementation

• Guidelines applicable worldwide
What is a Fuel Failure?

- Breach in the metal cladding surrounding fuel pellets
  - Radioactive materials leak into reactor coolant
  - Various causes
- **Not** a safety-related event
  - Radioactivity released to coolant is well below licensed limits
- May induce premature shutdown to replace fuel rods
- Impacts
  - Expensive: Up to $40-80 million per event (lost generation, inspection, replacement fuel)
  - Radiation: Unnecessary system and worker exposure
  - Public perception
U.S. Industry Failure Trend

- Smallest total number of failures recorded

Number of Failed Fuel Assemblies vs. EOC Year for PWR and BWR.
Fuel Integrity Initiative
Zero by 2010

“Take high impact actions to significantly improve fuel cladding performance in support of industry 2010 goals.”

INPO Board Sets Goal

Fuel Integrity Initiative Drafted

CNOs pledge support

Zero Failures

2006 2007 2008 2009 2010

EPRI Fuel Reliability Guidelines
First of a Kind

Fuel Surveillance & Inspection

PWR Corrosion/Crud

BWR Corrosion/Crud

Grid-to-Rod Fretting

Pellet Clad Interaction

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# EPRI Guidelines

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Status</th>
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<tbody>
<tr>
<td>Fuel Surveillance and Inspection Guidelines</td>
<td>Completed</td>
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<tr>
<td>PWR Fuel Cladding Corrosion and Crud Guidelines</td>
<td>Completed</td>
</tr>
<tr>
<td>BWR Fuel Cladding Corrosion and Crud Guidelines</td>
<td>Completed</td>
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<tr>
<td>Grid-to-Rod Fretting Guidelines</td>
<td>June 2008</td>
</tr>
<tr>
<td>Pellet Cladding Interaction Guidelines</td>
<td>August 2008</td>
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Guideline Development and Review

• Five guideline teams
  – More than 70 utility experts (including five international) and 25 fuel vendor experts
  – EPRI
  – Institute of Nuclear Power Operations
  – Nuclear Energy Institute
  – Industry consultants
• Guidelines based on thorough review of operating experience, fuel failure analyses, and fuel design and manufacturing procedures
• Reviewed by more than 200 industry experts
Guideline Structure

**Mandatory**
implemented at all plants where applicable

**Needed**
implemented wherever possible, but alternative approaches are acceptable

**Good Practice**
expected to provide significant operational and reliability benefits

- Categorization ensures appropriate level of field implementation
- Deviations require technical evaluation and responsible utility executive’s concurrence
Fuel Surveillance & Inspection Guideline

• EPRI Fuel Reliability Program Executive Committee:
  – “Fuel is the only component in our primary system that doesn’t come with an inspection and maintenance plan. ‘Run-to-failure’ is not an acceptable strategy.”

• Goal is for utilities to ensure acceptable fuel reliability via a knowledge-based understanding of their margin and of why they expect to have no failures.
# Fuel Surveillance and Inspection

**Mandatory and Needed Guidance**

<table>
<thead>
<tr>
<th>Mandatory</th>
<th>Needed</th>
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<tbody>
<tr>
<td>Establish a unit-specific surveillance and inspection program for non-failed fuel</td>
<td>Perform baseline, “healthy fuel” inspections</td>
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<tr>
<td>Establish a program to prevent the re-insertion of failed fuel</td>
<td>- PWRs: visual, oxide, and grid-to-rod fretting measurements</td>
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<tr>
<td>Perform causal analysis to establish apparent cause of failure</td>
<td>- BWRs: visual and oxide measurements</td>
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<td>Evaluate need for inspections following significant changes or events (e.g., fuel design, water chemistry, operational strategy)</td>
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<td>Enter inspection scope into EPRI’s Fuel Reliability Database (FRED)</td>
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## PWR Fuel Cladding Corrosion and Crud
### Mandatory and Needed Guidance

<table>
<thead>
<tr>
<th>Mandatory</th>
<th>Include a crud-induced corrosion risk assessment as part of the core design process for each cycle</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Assess effect of core and fuel design changes on critical factors controlling crud deposition, and take action to reduce crudding risk.</td>
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<td></td>
<td>Minimize locally high steaming rates on small fuel rod surface areas.</td>
</tr>
<tr>
<td>Needed</td>
<td>Maintain reactor coolant pHT $\geq 7.0$ while at full power xenon-equilibrium conditions. Beginning-of-cycle pHT should be as high as achievable within industry experience and vendor specified lithium restrictions.</td>
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<tr>
<td></td>
<td>Analyze reactor coolant during shutdown and startup at a frequency allowing reasonable estimates of nickel, iron and $^{58}$Co releases and removal.</td>
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<td>Optimize plant operating parameters that can affect sub-cooled nucleate boiling at all times during operating cycle.</td>
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# BWR Fuel Cladding Corrosion and Crud

**Mandatory and Needed Guidance**

<table>
<thead>
<tr>
<th>Mandatory</th>
<th>Incorporate a crud-induced corrosion risk assessment as part of the core design process for each reactor and cycle</th>
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<tbody>
<tr>
<td></td>
<td>Provide fuel vendor with anticipated fuel operating and environmental conditions for the reload.</td>
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<td></td>
<td>Review vendor’s fuel fabrication quality assurance program and planned quality control checks.</td>
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<td></td>
<td>Implement fuel handling procedures that provide for protection from mechanical damage and surface contamination until stored under water.</td>
</tr>
<tr>
<td>Needed</td>
<td>Review vendor-proposed changes in cladding alloy chemistry or material processing specifications.</td>
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<td>Ensure that new zirconium alloys will meet the corrosion, hydriding and mechanical property requirements of fuel designed for high exposure applications.</td>
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<td></td>
<td>Maintain feedwater oxygen within BWR chemistry guideline limits to minimize flow-assisted corrosion of carbon and low alloy steels.</td>
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<td></td>
<td>Assess risk of adverse fuel impacts before increasing quarterly average feedwater zinc concentration &gt;0.5 ppb or the cycle average feedwater zinc concentration &gt;0.4 ppb.</td>
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Guideline Rollout / Implementation

• Zero by 2010 = Dec 31, 2010
• Utilities will have six months to incorporate EPRI guidance into their programs
  – Actual implementation of mandatory, needed and good practices will take longer
• Recognizing that there is not enough time for all plants to perform healthy fuel inspections prior to 2011, a coordinated industry effort is underway to perform fuel inspections at “bounding” plants

Need to move quickly!
Together…Shaping the Future of Electricity