Fuel Performance Evaluation
Bruce Power & OPG CANDU Stations

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Introduction

Fuel Inspections

- Overview
- Equipment Currently in Use
- Irradiated Fuel Inspector Qualification and Training
- Inspection Procedures
- Technical Specifications
- Fuel Inspection Sheets

Bringing the Inspection Results into Service

- Overview
- Data
  - Trending
  - Flagging of artefacts / unusual observations
  - Feedback to station / Pressure Tube groups
- Fuel Performance Reporting
- Fuel & Fuel Channel Program
- Other analysis
  - Feed into PT scope of work
  - Waste management assessments
  - Mapping of fuel condition
  - Qualification of fuel designs

Limitations of NDE In-Bay Inspections

- Overview of current limitations
Introduction

- Improvements
- Design Limits
- Testing
- Design Concessions

- Incident analysis
- Safety analysis

- Defect and Incident Investigations
- Performance limits
- Operating Conditions
- Liaison with PT inspections

Design

Manufacturing

Operation

Fuel Handling

R & D

Waste Management

Fuel Integrity Degradation, Waste Fuel Handling

Fuel Performance
- Inspection
- PIE
Overview

- As per the yearly inspection plan, verify that fuel operating conditions are within the design limits

- Provide indirect information on the condition of the HTS, FC, and FH

- Provide a statistical measure of the condition of fuel in the core to verify that it is within the range assumed by safety analysis at the start of an accident

- Support incident investigations

- Provide information to determine the root cause of fuel defects

- Provide input for FC selection for PT inspections
Fuel Inspections

- Fuel bundles are inspected under water in the Irradiated Fuel Bay (IFB)
Fuel Inspections

- **Equipment**

  - **Handling tools**
  - **Debris collection tools**
  - **Bundle rotator**
  - **Under water periscope**
  - **Colour resolution standards**
Fuel Inspections

- Inspector Qualification and Training

- Level 1 Qualification
  - Fuel inspection course
  - ‘Hands-on’ training
  - 100 bundles inspected under the mentorship of a qualified inspector

- Level 2 Qualification
  - Develop experience in other areas
Fuel Inspections

- Inspection Procedures

- Ensure fuel bundles are being inspected in a systematic fashion

- Follow a set of prescribed steps

- Require inspectors to take specific photographs at specific times

- Require inspectors to record and photograph any unusual features
Fuel Inspections

- Technical Specifications
  - Provide visual benchmarks
  - Standardize the data obtained from inspections
  - Ensure artefacts are recorded consistently from station to station
  - Lead to creation of semi-quantitative data

How to record BMI and SSI on Inspection Sheet 01 (IS01):
Fuel Inspections

- Inspection Sheets

<table>
<thead>
<tr>
<th>Station-Unit:</th>
<th>Serial #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel:</td>
<td>Up or Downstream:</td>
</tr>
<tr>
<td>In-core positions:</td>
<td>No of e/p cracks:</td>
</tr>
<tr>
<td>Disch Date:</td>
<td>Inspected by:</td>
</tr>
<tr>
<td>Insp. Date:</td>
<td>Image #:</td>
</tr>
</tbody>
</table>

Fuel Inspection Sheet for 17 Element Fuel (Both sides of this form must be completed)

- Fuel Inspection Sheet
- 17 Element Fuel
- Both sides of the form must be completed

Diagram showing the layout of ELT 18 and ELT 1.
Overview

- Data and images are input, verified and stored in a centralized Fuel Inspection Database (FID).

- Use of a standard set of specifications enables semi-quantitative data to be defined that is sufficient for trending and analysis.

- Historical inspection records and images are retrieved and compared to new and/or unusual artifacts.

- To date, there is inspection data for more than 10,000 bundles stored in FID which includes over 400 confirmed defects.
Bringing the Inspection Results into Service

- Trending data

- Once entered and verified in the database, each bundle can be searched based on its inspection artefacts

- Each reactor unit can be mapped for inspected bundle populations

- Observable artefacts can be tracked and mapped

- This data forms the basis for compliance reporting

Distributions of inspected bundles are easily sorted with FID
Bringing the Inspection Results into Service

- Trending data

*Distributions of artefacts occurrences can be tracked over time using FID.*
Bringig the Inspection Results into Service

- Trending data

Distributions of artefacts occurrences can be tracked over time using FID
Bringing the Inspection Results into Service

- Flagging unusual artefacts
  - Feedback to station
  - OPEX searches
  - Trigger follow-up inspections

Unusual, or seldom seen artefacts will initiate numerous activities
Bringing the Inspection Results into Service

- Feeding into Pressure Tube Scope of Work
  - Debris fretting
  - Acoustic channels
  - Unusual interactions

Unusual scrapes indicating excessive interaction with the pressure tube
Bringing the Inspection Results into Service

- Compliance Reporting to the CNSC
  - CNSC S-99 requirement
  - CAN/CSA-N286.5-95 Section 6.7.2
  - Demonstrate adequate monitoring of the fuel condition
  - Verify that fuel condition meets the fuel design basis limits

*Yearly reports are delivered to the CNSC confirming the fuel is operating within the design basis limits and that inspection results during the year were acceptable.*
Bringing the Inspection Results into Service

- Fuel & Fuel Channel Program
  - Results are fed back through the F&FCP
  - Serves to provide Station with inspection highlights
Bringing the Inspection Results into Service

- Other Analysis – Waste Management

Data obtained over the years has assisted to validate numerous models and codes used in fuel integrity analysis.
Bringing the Inspection Results into Service

- Mapping of Fuel Condition

Generic Core Map of Debris or Debris Fretting Indications
(Number of bundles in FID discharged 2005-2009)

Legend:
- Total Occurrences 161
- Number of occurrences equal to or greater than 5
- Number of occurrences equal to or greater than 2 but less than 5
- Number of occurrences equal to or greater than 1 but less than 2
Bringing the Inspection Results into Service

- Other Analysis – Qualification of Fuel Designs

Semi-quantitative spacer pad wear data collected by inspectors over time has supported design changes such as the 37M bundle.
Limitations of In-Bay Inspections

- Harsh environment for equipment
  - equipment exposed to high radiation fields
  - no plastics, electronics, or parts requiring grease
  - glass lenses darken over time, reducing inspection quality
  - poor lighting
  - maintenance is difficult

*Conditions in the IFB can make visual examination challenging at times (debris-covered periscope lens pictured here)*
Limitations of In-Bay Inspections

- Inspection capability limited to NDE
  - DE can only be completed by shipment to AECL Chalk River for Post-Irradiation Examination (PIE)
  - PIE is very costly ($)
  - DE results take years
  - Efforts made to enhance in-bay capability
  - FEMER developed (Fuel Envelope MEasuring Rig)

Tools such as FEMER have been designed to enhance in-bay bundle profiling capabilities
Questions?

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