COG Risk Informed In-Service Inspection (RI-ISI) Pilot Study

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Outline

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Background

- Traditional in-service inspection programs
  - CSA N285.4 for Canada, ASME BPVC Section XI for U.S.
  - Based on defense-in-depth concept
  - Use deterministic rules
  - Developed using release rates, stress levels and fatigue usage
- Augmented inspection programs developed for specific degradation mechanisms.
  - Experience shows degradation occurs where prescribed conditions exist.
- Industry evolution under way toward risk-informed approach for more consistency and incentives to reduce dose exposures and costs.
- Inspection models moving from “inspection for confirmation” to “inspection for cause”.
RI-ISI Methodology

- Determine Scope
- Perform consequence of failure assessment
  - Based on Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) ~ Large Release Frequency (LRF) in CANDU
  - Considers break size, direct effects, indirect effects, containment performance
- Perform failure potential assessment
  - Based on Pipe Rupture Potential of degradation mechanisms
  - Mechanisms evaluated include Thermal Fatigue (TASCS, TT), Stress Corrosion Cracking (IGSCC, TGSCC, PWSCC, ECSCC), Localized Corrosion (MIC, PIT, Crevice Corrosion), Erosion/ Cavitation, Flow-Accelerated Corrosion (FAC)
- Perform service history review
RI-ISI Methodology

- Perform risk ranking (determine risk category)

  ![Consequence Evaluation Diagram]

- Select elements for inspection
  - Percentage of elements selected for inspection depends on the risk category
  - Considers plant service history, severity of postulated degradation mechanisms, accessibility, inspectability, radiation exposure

- Perform risk impact assessment
CNSC RI-ISI Guideline

- It provides high level expectations for development of alternate piping inspection programs.
- Given the international trend to move to RI-ISI, COG established a RI-ISI WG in 2008 to establish common Canadian utility position on RI-ISI.
- COG performed a pilot study to:
  - Develop or select a CANDU best fit RI-ISI methodology
  - Implement the methodology on several selected systems
  - Perform delta risk assessment {CSA N285.4 vs. RI-ISI}
  - Explore risk reduction opportunities
COG RI-ISI Pilot Study

- **Scope included** piping welds in:
  - Main and Auxiliary Primary Heat Transport (PHT)
  - Shutdown Cooling (SDC)
  - Emergency Coolant Injection (ECI)
  - Boiler Feed (BF)
  - Main Steam (MS)

- **Scope covers:**
  - Both nuclear and non-nuclear piping
  - Systems selected and systems exempt under CSA N285.4
  - Systems outside the scope of CSA N285.4
  - Systems with augmented inspection programs (FAC)
  - Systems with significant impact on core damage frequency

- Darlington Unit 2 selected.
Results – PIP Scope

- CSA N285.4 sampling rules require ~40 locations excluding monitoring inspections.
- PIP Selections = 69 selections (6.9%) including monitoring and partial inspections.
- ASME Selection would be 25% of 998 welds = 250 selections.
- EPRI Selections = 6 selections (2.4%) excluding monitoring inspections.
- Equivalent Reactor Coolant Pressure Boundary (RCPB) scope for COG would be greater than 998.
- EPRI Selections are typically around 10% of RCPB in US.
Results – PIP Scope

- Reason for Difference: CANDU Loss of Coolant Accident (LOCA) Conditional Core Damage Probability (CCDP) is Medium Consequence versus High Consequence in LWR (BWR/PWR) designs.
- Piping has Low to Medium Consequence (Low Risk).
- Majority of piping is not subject to any degradation.
- High risk welds are already selected in CSA N285.4.
- Opportunity for reduction in dose and cost in PIP scope.
- Small potential for significant risk reduction due to absence of degradation and low CCDP.
- Impact of implementing PIP scope reduction is negligible (2E-11 in plant risk).
# Results – PIP Scope

## Table 1: PIP Scope – Estimated Dose and Time

<table>
<thead>
<tr>
<th>System</th>
<th>UT Inspection time per patch (h)</th>
<th>Estimated dose per patch (mrem/h)</th>
<th># of patches</th>
<th>Total UT Inspection Time (h)</th>
<th>Total Estimated Dose (mrem)</th>
<th># of patches</th>
<th>Total UT Inspection Time (h)</th>
<th>Total Estimated Dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Heat Transport System – Main Circuit Piping (3310)</td>
<td>2</td>
<td>15</td>
<td>20</td>
<td>40</td>
<td>600</td>
<td>4</td>
<td>8</td>
<td>120</td>
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<tr>
<td>Primary Heat Transport System – Main Circuit Piping TI Welds (3310)</td>
<td>8</td>
<td>15</td>
<td>3</td>
<td>24</td>
<td>360</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Primary Heat Transport System – Reactor Inlet/Outlet Headers (3314)</td>
<td>2</td>
<td>25</td>
<td>6</td>
<td>12</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pressure &amp; Inventory Control System – Bleed and Relief Circuit Piping (3332)</td>
<td>4</td>
<td>10</td>
<td>5</td>
<td>20</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pressure &amp; Inventory Control System – Pressurizer Circuit Piping (3333)</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>20</td>
<td>2</td>
<td>4</td>
<td>40</td>
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<tr>
<td>Shutdown Cooling System Piping (3341)</td>
<td>2</td>
<td>10</td>
<td>28</td>
<td>56</td>
<td>560</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Emergency Coolant Injection System Piping (3432)</td>
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<td>15</td>
<td>6</td>
<td>12</td>
<td>180</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>69</strong></td>
<td><strong>166</strong></td>
<td><strong>2220</strong></td>
<td><strong>6</strong></td>
<td><strong>12</strong></td>
<td><strong>160</strong></td>
</tr>
</tbody>
</table>

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**4TH INTERNATIONAL CANDU IN-SERVICE INSPECTION WORKSHOP**

**NDT IN CANADA 2012 CONFERENCE**

**TORONTO JUNE 18-21**
Results – Non PIP Scope

- ASME Selections would be 25% of Class 1, 7.5% of Class 2.
- PIP Selections = 0.
- EPRI Selections = 88 (10% of total) for Case 1.
- EPRI Selections = 28 (3% of total) for Case 2 (less conservative) as follows:
  - ECI (outside containment) = 13, BF = 8, MS = 7
- EPRI Selections are typically much less than 88 for Case 1.
- Reason for Difference:
  - CANDU MS and BF are High Consequence versus Medium Consequence in LWR (BWR/PWR) designs.
  - ECI is High Consequence (no physical train separation & no isolability) versus Medium Consequence in LWR (BWR/PWR) designs.
Results – Non PIP Scope

- Piping is not susceptible to degradation (FAC dealt with separately under FAC program).
- With the exception of portions of ECI, BF and MS systems, piping has Low to Medium Consequence.
- Less conservative analysis performed to reduce CCDP and use other methods than Non Destructive Examination, such as regular pressure testing and pressure monitoring, to manage risk.
- For the MS, BF and ECI systems, there is a decrease in plant risk with additional inspections, although the decrease is very small.
- For the Non-PIP scope, no change to the number of inspections in the PHT system is required.
Summary

- EPRI RI-ISI methodology can be adapted to the CANDU design.
- Degradation mechanisms in EPRI RI-ISI methodology are consistent with the CANDU experience.
- CSA N285.4 has an implicit risk-related rationale that includes conservatism in the PIP scope.
- Results indicate negligible delta risk in moving from CSA N285.4 to RI-ISI.
- Need to discuss minimum number of PHT inspections with regulator.
- Multi-unit inspection reductions may be considered in applying RI-ISI to multiple identical units (rare in US).
Path Forward

- Pilot Study results were presented to CNSC at the industry meeting on October 11-12, 2011.
- RI-ISI report was shared with CSA N285B Technical Committee to consider:
  - Potential implementation of RI-ISI in development of CSA N285.7 (Periodic Inspection of Conventional Systems)
  - Reviewing of exemption Clause 3.3.2 in CSA N285.4
  - Introducing RI-ISI as an alternative/non-mandatory method for defining scope of inspection (i.e. non-mandatory Annex). This is also a CNSC consideration communicated to COG earlier.
- CNSC Guideline on enhancements for RI-ISI application will be consolidated in CSA N285.4 Standard.
QUESTIONS?