Crystal River Unit #3

Presentation to PNSC
Containment Update & Discussion
of Repair Options

November 16th, 2009
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Steam Generator Replacement (SGR) Opening
(between Buttresses 3 and 4)

SGR Opening Dimensions
- Outer: 25' 6" x 24' 0"
- Concrete Opening: 16' 0" x 27' 0"

Hydro-Demolition & Liner Removal Sequence

Delamination Close-up

Condition Assessment Techniques

Completed or Planned
- Impulse Response (IR) Scanning of Containment Wall Surfaces
  - Comprehensive on external exposed surfaces
  - Representative sampling inside buildings
- Core bores
  - Use to cross-check IR results
  - Includes visual inspection/documentation of surface inside the bored hole
- IWL visual inspection of containment external surface (affected areas)
- Dome Inspections
  - IR scans in selected areas
  - Core bore samples in repaired and non-repaired areas
  - Physical survey (compared to 1976 results)

Location of the Delamination

Note: Figures include an illustrative scale and map of repair areas.
Containment "Unfolded" - Buttress 2 to 5
Updated Nov 16th. Mosaic IR Overlay scale is approximate

Core Bores
Buttress Spans 2-3-4-5 (as of Nov 14th 2009)

Core Bores
Buttress Spans 5 - 6 - 1 - 2 (as of Nov 14th 2009)

Core Borings

Tendon Pattern
Tendon Pattern at time of cutting SGR Opening
--- Excavated Tendon
--- Excavated Tendon
Root Cause Analysis – P11 Metrics
Un-refuted Failure Modes as of Nov 9th 2009

- External Events
- Operational Events
- Inadequate Containment Cutting
- Inadequate Concrete - tendon anchorage
- Discharge, Creep, and Settlement
- Chemical or Environmentally Induced Failing
- Inadequate Use of Concrete Materials
- Inadequate Concrete Construction
- Inadequate Concrete Design due to High-Level Stress

Field Data Acquisition

- Impulse Response (IR) Scans
- Boroscopic Inspections
  - Core bore holes
  - Inside the delaminated gap
- Visual inspections
  - Delamination cracks at SGR Opening
  - Larger fragments from concrete removal process
  - Containment external surface

Field Data Acquisition (continued)

- Nearby energized tendons lift-off (vertical and horizontal)
- Containment ID measurements
- Strain gauge measurements
- Linear variable displacement transducer (LVDT) gap monitoring
- Building Natural Frequency

Field Data Acquisition (continued)

- Core bores laboratory analysis
  - Petrographic Examination
  - Modulus of Elasticity and Poisson's Ratio
  - Density, Absorption, and Voids
  - Compressive Strength, Splitting Tensile Strength, and Direct Tensile Strength

MPR 3D FE Model
Model Features

- 180 degree Symmetric model
  - Symmetry plane @ 150 degrees midway between Butresses 3 & 4 / 1 & 6
  - '18 Opening, '18 Damage & Hatch Modeled Explicitly
- Concrete Model
  - Brick elements for all components
  - Dome and Base modeled independently
  - Simplified ring beam and buttress geometry
  - Constraint equations used to join dome and ring girder for meshing efficiency
  - Constraint equation used to model sloped surfaces of the hatch
- Liner Model
  - Shell mesh with variable thickness
  - Shared nodes with containment inner surface
- Tendon Modelling
  - Hoop tendons modeled explicitly for release and re-tensioning
  - Vertical Tendons modeled explicitly for release and re-tensioning
  - Dome tendons modeled independently with forces ported to global model
### Specific Analysis to be Performed

<table>
<thead>
<tr>
<th><strong>Existing Design Cases for Comparison</strong></th>
<th><strong>Planned Analysis Sequence</strong></th>
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</thead>
<tbody>
<tr>
<td>w Gravity (.95 G)</td>
<td>w Dead Load + Tendons</td>
</tr>
<tr>
<td>w Internal Dead Load (200 puff)</td>
<td>w Remove Hoop + Vertical Tendons in SGR Opening</td>
</tr>
<tr>
<td>w Tendons (163 kips / tendon)</td>
<td>w Remove SGR Opening</td>
</tr>
<tr>
<td>w Include cases</td>
<td>w Delamination(G)</td>
</tr>
<tr>
<td>w Internal Pressure (55 psi)</td>
<td>w Remove Additional Hoop &amp; Vertical Tendons</td>
</tr>
<tr>
<td>w Wind Pressure (0.55 psi)</td>
<td>w Replace the SGR Plug</td>
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<tr>
<td>w Seismic</td>
<td>w Re-tension Tendons</td>
</tr>
<tr>
<td>w Accident Thermal</td>
<td>w SAVE Path Dependent Model for Starting point to Run 5 Controlling Design cases</td>
</tr>
</tbody>
</table>

### Repair Alternatives Considered

- **Use-as-Is**  
- **Anchorage Only**  
- **Cementitious Grout**  
- **Epoxy Resin**  
- **Delamination Removal and Replacement**

### Repair Attributes

- **Incorporates and is compatible with Root Cause Analysis findings**
- **Design Basis Controlling Load Steps**
  - Incorporates Life of Plant Considerations
  - Long Term Surveillance and/or Maintenance Requirements
  - License Renewal
  - Constructability

### Repair Alternatives

- **Use as Is** - Rejected  
  - Degraded safety related structure  
  - Design margins are reduced
- **Anchorage Only** - Rejected  
  - Containment and delaminated layer will not structurally perform as monolithic shell  
  - Would function as two independent shells pinned together  
  - Detensioning is not expected to close the delamination gap (greater than 2" in some places)  
  - Would require some competent fill material be added  
  - Anchorage plate washers (acting to distribute the load) would have minimal separation creating difficulty in the field  
  - Tendons are not always equally spaced  
  - Rebar mat interference at targeted anchorage locations
**Repair Alternatives**

**Cementitious Grout**

- **Rejected**
  - Will not be able to penetrate all of the fissures observed along the delaminated surface
  - Creates un-repaired weak planes, affecting tensile capacity
  - Multi-fissure segmented cracking and dislodgement could block adjacent areas from being filled
  - Mock-up testing to simulate all of the in-situ conditions is problematic
    - Examples - Cleanliness of surfaces, parallel fissures
    - Would likely require in-situ testing that would be difficult to control in the field

**Epoxy Resins**

- **Rejected**
  - Not viable in gaps greater than 1/2" due to exothermic reaction
    - Delamination gaps are well beyond this limit, including > 2" in some locations
  - May not be able to penetrate all of the fissures observed along the delaminated surface
    - Creates un-repaired weak planes, affecting tensile capacity
  - Raising the injection pressure to improve penetration in fissures
    - Anchorage becomes more difficult
    - Tendon conduit integrity becomes more difficult
  - Mock-up test needed to validate tendon duct integrity (leak tightness against epoxy injection)
    - Test may indicate leak tightness is not assured

**Repair and Replacement**

- **Delamination Removal and Replacement - Selected**
  - Delamination Removal Challenges
    - Safe removal of delaminated concrete at elevated heights
    - Avoiding collateral damage to tendon conduits
    - Minimize damage to the remaining substrate to minimize concrete branding and to provide a favorable bonding surface
    - Requires verification planar fissures are removed
  - Requires new radial reinforcement design (anchored to the substrate)
  - Will require treatment of planar fissures (if encountered) at periphery

- **Repair and Replacement - Selected (continued)**
  - Need to secure and verify same constituents to use the existing qualified design concrete mix (for the SGR Opening)
  - Concrete Placement
    - Needs to construct ganged forms for placing the pours
    - Need to determine method to anchor the forms
    - Elevations create work execution challenge
Questions