Crystal River Unit #3
Containment Delamination Investigation & Repair

March 9, 2010
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Progress Energy

Agenda

- CR#3 Containment Design Features
- SGR Opening Sequence & Identification of Delamination
- Investigative Approach
- Condition Assessment
- Operational Experience (OE)
- Root Cause Analysis (RCA)
- Design Basis Analysis (DBA)
- Repair Sequence
- Summary Comments / Questions

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CRYSTAL RIVER #3 DESIGN FEATURES

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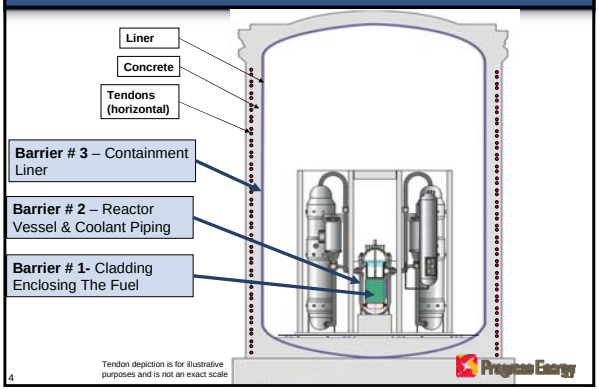
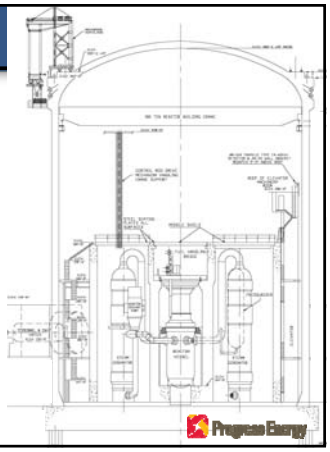
Fission Product Barriers
Simplified Schematic



CR3 Containment Dimensions

Dimension	Value
Containment Outside Dimension (OD)	137 ft 0.75 in
Dome Thickness	36 in
Basemat Thickness	12 ft 6 in
Liner Thickness	0.375 in
Wall Thickness	42 in
Buttress Wall Thickness	5 ft 10 in
Vertical & Hoop Conduit OD	5.25 in
# of Vertical Tendons	144
# of Tendon Hoops	94
# of Tendons per Hoop	3
# of Prestressed Dome Tendons	123



SGR OPENING SEQUENCE & IDENTIFICATION OF DELAMINATION

Steam Generator Replacement (SGR) Opening
(between Buttresses 3 and 4)

SGR Opening Dimensions
@ Liner
23' 6" x 24' 9"

@ Concrete Opening
25' 0" x 27' 0"

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Concrete Removal

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Concrete & Liner Removal Sequence

1

2

3

4

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Delamination Close-up

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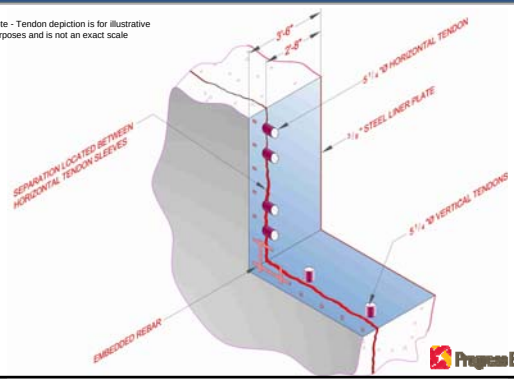
Location of the Delamination

Note - Tendon depiction is for illustrative purposes and is not an exact scale



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INVESTIGATION APPROACH

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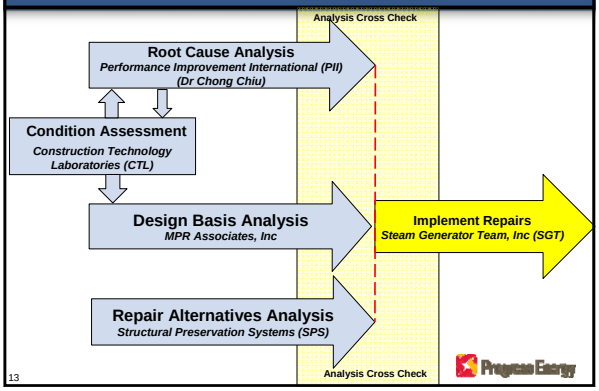
Overall Work Flow Summary



External Support

- **Condition Assessment & Laboratory Testing**
  - NDT - ***Construction Technology Laboratories (CTL)***
  - Labs - *MacTec, Soil& Materials Engineers (S&ME)*
  - Other Field Data - *Sensing Systems, Inc; Core Visual Inspection Services (Core VIS), Nuclear Inspection & Consulting, Inc; Precision Surveillance; Gulf West Surveying Inc; AREVA*
- **Root Cause Analysis**
  - Lead - ***Performance Improvement International (PII)***
    - Numerous PhD's (11) with expertise in root cause investigation techniques, nuclear engineering, nuclear operations & maintenance, material science & testing, concrete standards & construction, concrete testing, concrete creep, concrete fracture, human performance, process analysis, containment analysis, reliability and computer modeling
  - Owner's Support - *Worley Parsons, Bechtel*

External Support (cont)

- **Design Basis Analysis**
  - Lead - ***MPR Associates, Inc.***
  - Owner's Support - *Worley Parsons*
- **Repair Alternatives Analysis**
  - Lead - ***Structural Preservation Systems (SPS)***
  - Owner's Support - *Wiss, Janney, Elstner, Inc (WJE)*
- **Industry Peer Support**
  - *Exelon, SCANA, and Southern Company*

Nuclear Safety Oversight Committee (NSOC)
Containment Sub-Committee Membership

Member	Title
John Elnitsky (PGN)	VP - Nuclear Plant Development **(Chairman)**
Joe Donahue (PGN)	VP - Nuclear Oversight
Chris Burton (PGN)	VP - Harris
Greg Selby	Technical Director - EPRI
Dr. Shawn Hughes	VP - Shaw Stone & Webster
Dr. Paul Zia	Civil Engineering Professor, NCSU
Hub Miller	33 years industry oversight experience
Darrell Eisenhut	41 years industry operation and oversight experience

CONDITION ASSESSMENT

Condition Assessment Activities

- **Determine Extent of Condition**
  - Characterize the extent of delamination at the SGR opening
  - Determine condition of other portions of structure
- **Non-Destructive Testing (NDT) of Containment Wall Surfaces**
  - Use of Impulse Response (IR) Method
  - Comprehensive on external exposed surfaces
  - Accessible areas in adjacent buildings

Condition Assessment Activities (cont)

- **Concrete Cores**
  - Used to confirm IR results (over 116 cores)
  - Visual examination of core bore holes with boroscope to identify if delamination present
- **ASME Section XI IWL Visual Inspection** (affected areas)
- **Containment Dome Inspections**
  - NDT IR scans in segment above the SGR opening
  - Concrete cores with boroscope examination of bore holes
  - Physical survey with established benchmarks

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Condition Assessment Techniques
Impulse Response (IR)

- IR Equipment
  - Primary test method used in this evaluation
- IR Performed in the Field

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Condition Assessment Techniques
Ground Penetrating Radar (GPR)

- Ground Penetrating Radar (GPR) Equipment
  - Locates internal features (rebar, tendon conduits, etc.)
- GPR Performed in the Field

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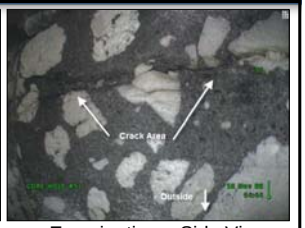
Condition Assessment Techniques
Impact Echo (IE)

- IE Equipment
  - Ability to determine depth of delamination
- IE Performed in the Field

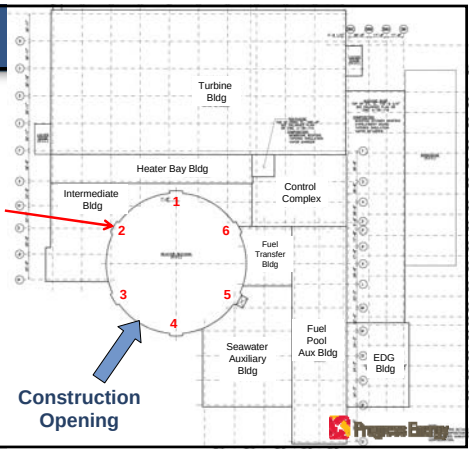
Condition Assessment Techniques
Core Bores & Boroscopic Examination

Examination – Inward View



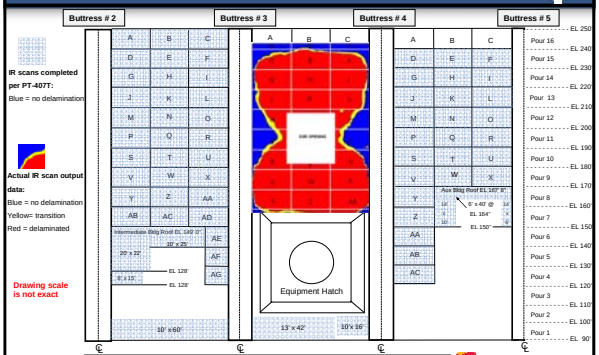
Examination – Side View

Plan View



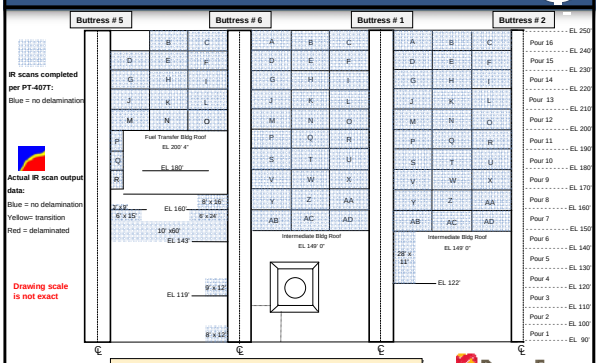
Containment "Unfolded" – Buttress 2 to 5

Mosaic IR Overlay scale is approximate



Conclusion – IR scans with confirmation core bores identified delamination only in the Buttress 3-4 span above the Equipment Hatch, as shown in red above

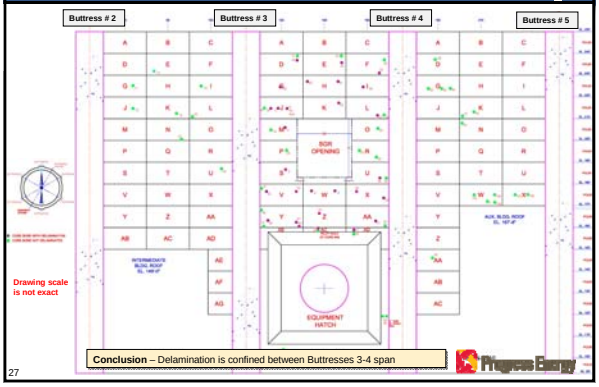
Containment "Unfolded" – Buttress 5 to 2



Conclusion – No delamination identified in these Buttress spans

Core Bores

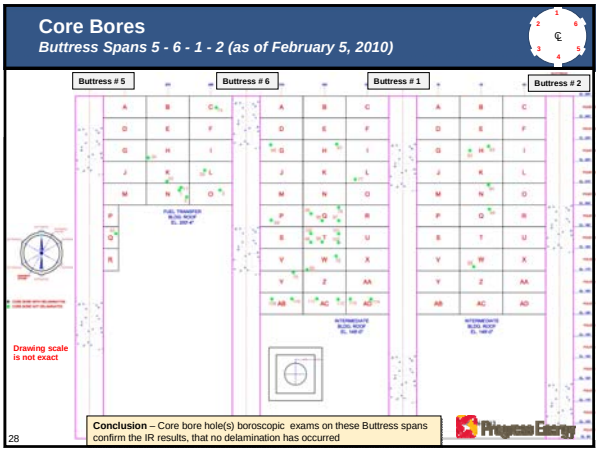
Buttress Spans 2 - 3 - 4 - 5 (as of February 5, 2010)



Conclusion – Delamination is confined between Buttresses 3-4 span

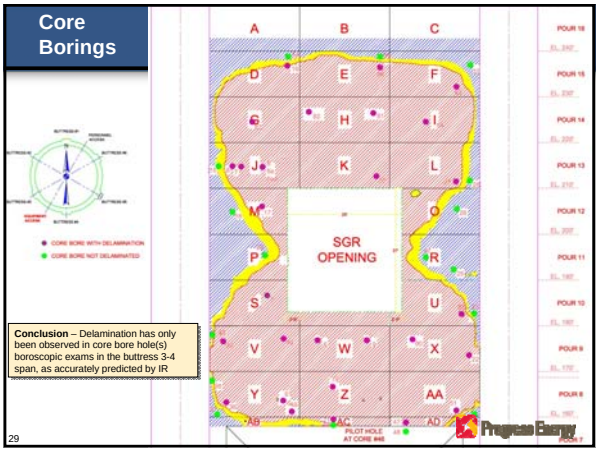
Core Bores

Buttress Spans 5 - 6 - 1 - 2 (as of February 5, 2010)



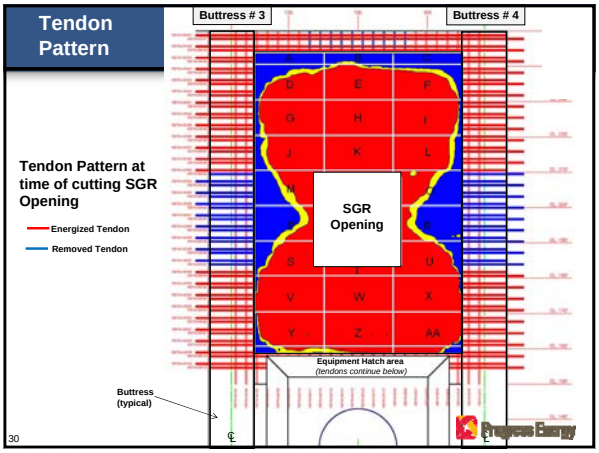
Conclusion – Core bore hole(s) boroscopic exams on these Buttress spans confirm the IR results, that no delamination has occurred

Core Borings



Conclusion – Delamination has only been observed in core bore hole(s) boroscopic exams in the buttress 3-4 span, as accurately predicted by IR

Tendon Pattern



OPERATIONAL EXPERIENCE (OE)

Concrete OE

- **Worley Parsons**
  - 1976 dome delamination investigation and repair (as Gilbert / Commonwealth)
- **Structural Preservation Systems (SPS)**
  - Largest Concrete Repair Contractor in the US, 2nd largest Concrete Contractor (of any type) in the US
    - Defects, Damage, and Deterioration
  - Performs > 4,000 repair projects per year
- **Wiss, Janney, Elstner, Inc (WJE)**
  - Structural engineering and materials science firm specializing in failure investigations and problem solving
  - Specialist in structural condition assessments and design of repairs and retro-fits for reinforced and post tension concrete structures
  - Conducted original CR3 Structural Integrity Test (SIT)

ROOT CAUSE ANALYSIS

Root Cause Analysis (RCA)

- **75 potential failure modes considered**
- **Failure Mode Categories Included:**
  - Design & Analysis
  - Concrete Construction
  - Use of Concrete Materials
  - Shrinkage, Creep and Settlement
  - Chemically or Environmentally Induced Distress
  - Concrete – Tendon – Liner Interactions
  - SGR Containment Cutting
  - Operational Events
  - External Events

Root Cause Analysis
Field Data Acquisition

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

Root Cause Analysis
Field Data Acquisition (continued)

- Nearby energized tendons lift-off (vertical and horizontal)
- Containment dimension measurements
- Strain gauge measurements
- Linear variable displacement transducer (LVDT) gap monitoring
- Building natural frequency

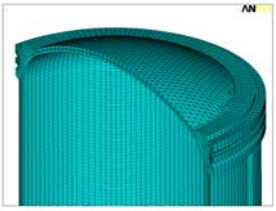
Root Cause Analysis
Field Data Acquisition (continued)

- **Core Bores Laboratory Analyses**
  - Petrographic Examination
  - Modulus of Elasticity and Poisson's Ratio
  - Density, Absorption, and Voids
  - Compressive Strength, Splitting Tensile Strength, and Direct Tensile Strength
  - Accelerated Creep Test
  - Accelerated Alkali Silica Reaction (ASR) Test
  - Chemistry and Contamination Test
  - Scanning Electron Microscope (SEM) Examination of Micro-Cracking

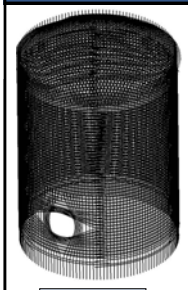
Root Cause Analysis

- 65 Failure Modes Refuted
- Remaining 10 Failure Modes were Combined for Root Cause Analysis (with 3D Fracture Analysis and Various Special Tests) to Determine their Significance (if any)
- **Delamination Occurred as a Result of Outage Activities to Create an Opening for Steam Generator Replacement**

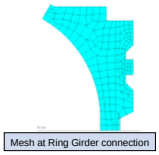
DESIGN BASIS ANALYSIS



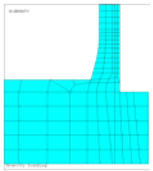
MPR Design Basis Analysis
Finite Element Analysis (FEA) Model Details



Modeling of Tendons



Mesh at Ring Girder connection



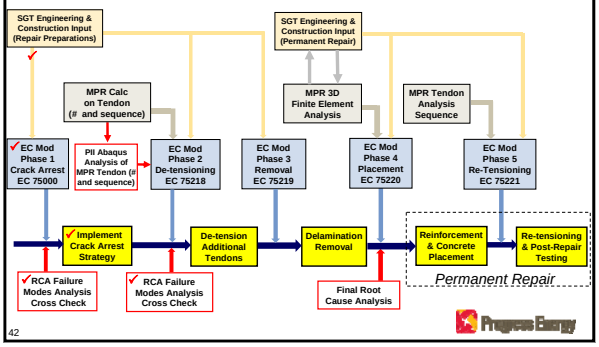
Mesh at Foundation connection

Composite FEA Model

REPAIR SEQUENCE

Engineering & Repair Work Flow

✓ Indicates Completed Task



Summary & Questions

- Design is Acceptable for Normal and Emergency Operations
- Construction was in Accordance with Design
- Delamination Occurred during the Outage
- Investigation was Thorough and Comprehensive
- New State-of-the-Art Analytical Methods Had to be Created to Analyze Containment Response