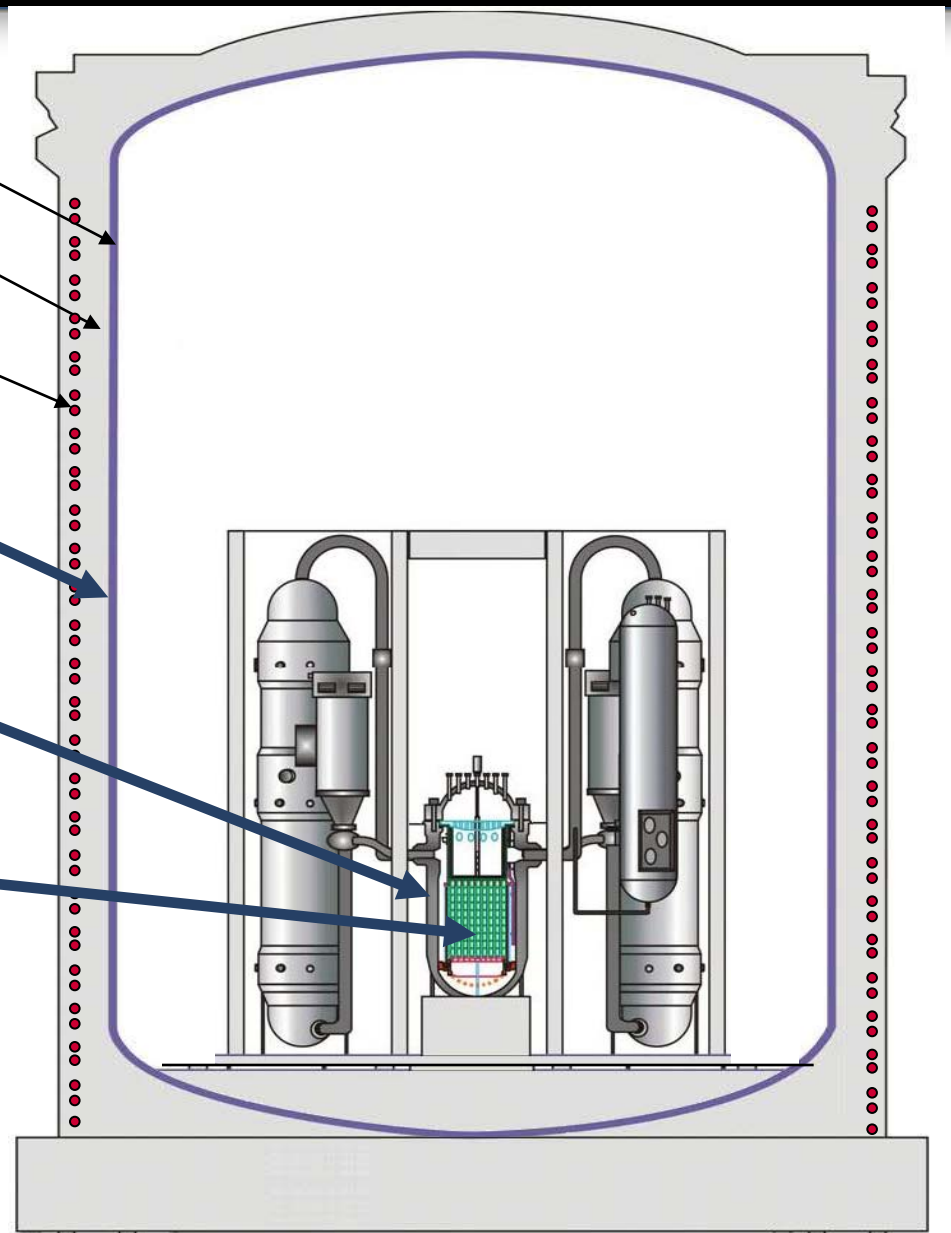
Crystal River Unit #3 Containment Investigation and Repair

September 2, 2010

Progress Energy

Fission Product Barriers
Simplified Schematic



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

Steam Generator Replacement Opening

Identification of Issue

SGR Opening Dimensions

@ Liner
23’ 6” x 24’ 9”

@ Concrete Opening
25’ 0” x 27’ 0”

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Root Cause Analysis
Investigation & Design Basis Team

- **Comprehensive Team Commissioned**
  - Progress Energy personnel - expertise across fleet
  - Industry peers:
    - *Exelon*
    - *Southern Company*
    - *SCE&G*
  - External expertise:
    - *Performance Improvement International (PII)*
    - *MPR Associates*
    - *AREVA*
    - *Worley Parsons*
    - *Wiss, Janney, Elstner Associates (WJE)*
    - *Construction Technology Laboratories (CTL)*

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Root Cause Analysis

Investigation & Design Basis Team (continued)

- **Material Laboratories Support**
  - *MacTec*
  - *Soil & Materials Engineers (S&ME)*

- **Field Data Support**
  - *Sensing Systems, Inc*
  - *Core Visual Inspection Services (Core VIS)*
  - *Nuclear Inspection & Consulting, Inc*
  - *Precision Surveillance*
  - *Gulf West Surveying, Inc*
  - *AREVA*

Root Cause Analysis

Investigation & Design Basis Team (continued)

- **Numerous PhDs (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*
  - *Computer Modeling*

Concrete Operational Experience (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
  - Performs > 4,000 repair projects per year
- **Wiss, Janney, Elstner Associates, 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)

Nuclear Safety Oversight Committee (NSOC)

Containment Sub-Committee Membership

Member	Title
John Elnitsky (PGN)	VP – New Generation Programs and Projects **(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

Root Cause Analysis

Investigation Approach

- **Complex Investigation with 75 Potential Failure Modes Considered**
- **Non-Destructive Testing (NDT) of Containment Wall Surfaces**
  - Use of Impulse Response (IR) Method and Ground Penetrating Radar (GPR)
    - Over 8,000 IR data points taken
  - Comprehensive on all accessible areas
- **Concrete Core Bores**
  - Over 150 core bores performed
  - Ranged from 1” to 8” diameter, 6” to 32” long
  - Validated Impulse Response (IR) data, along with boroscopic inspections
  - Laboratory testing

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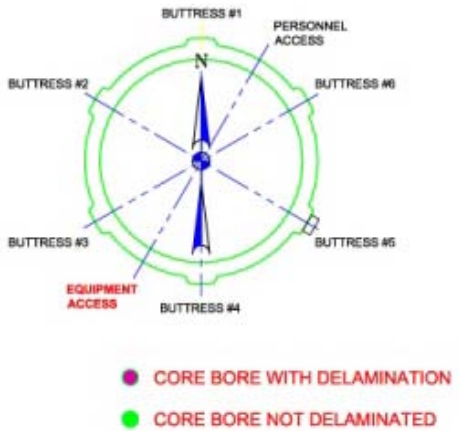
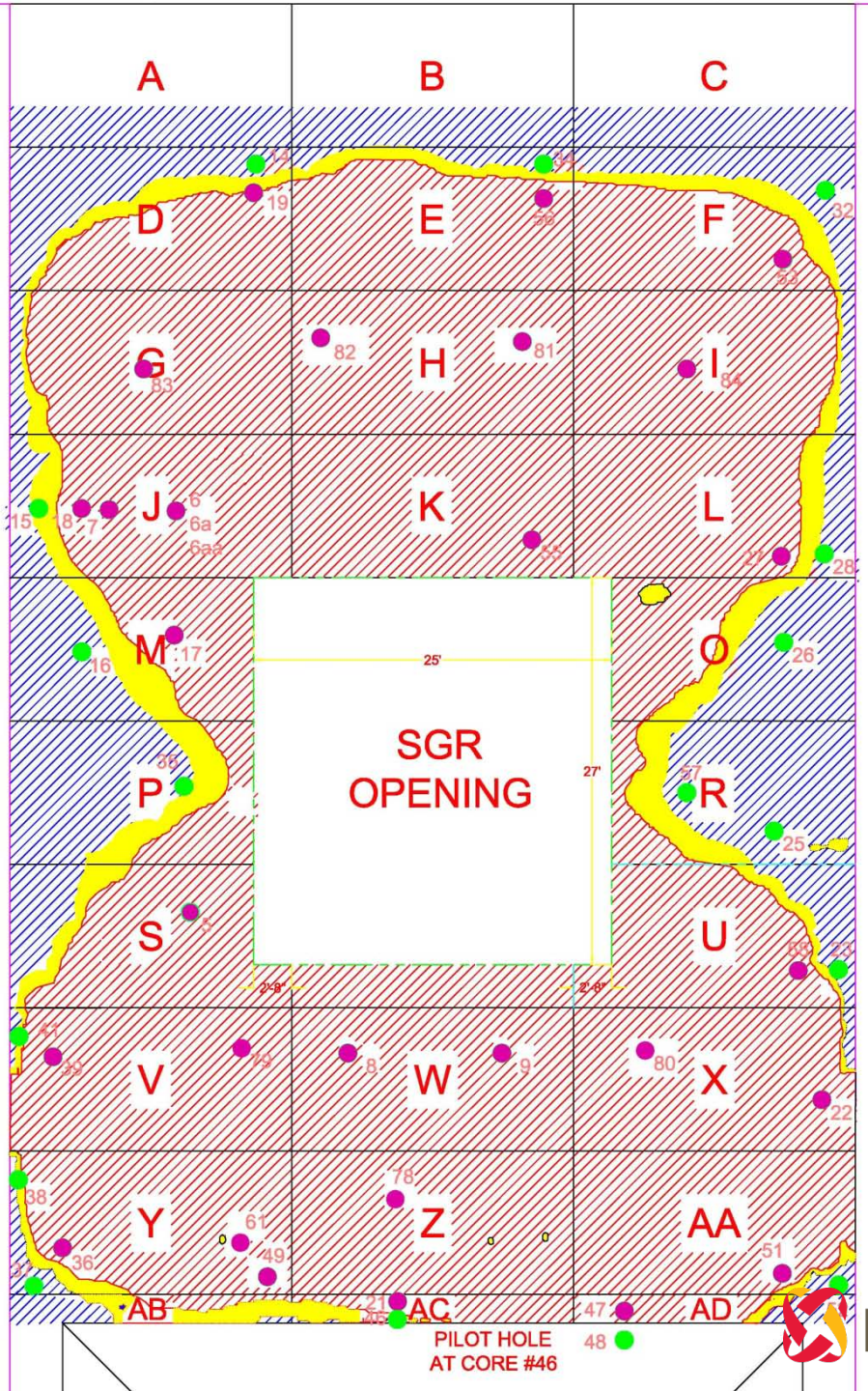
Core Borings



Conclusion – Physical observation of core boring has validated the delamination boundary, as accurately predicted by Impulse Response (IR).



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Root Cause Analysis
Laboratory Analysis

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

Root Cause Analysis

Finite Element Analysis (FEA) Modeling Tools

- **Existing Industry Analysis Techniques Predicted Acceptable Margin to Delamination at CR3**

- **Investigation Required Development of New FEA Tools of Progressively Increasing Complexity based on Data Obtained from the Delamination**
  - 360^{o} global containment model
  - Visco-elastic / non-linear model
  - Model includes individual tendons, rebar, liner, etc.
  - Sub-models (1” mesh) provide higher resolution of localized behavior

Root Cause Analysis
Summary

- **Conclusions**
  - 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

- **Root cause:** De-tensioning scope and sequence resulted in redistribution of stresses that exceeded tensile capacity
  - *Could not have been predicted based on existing information and models at that time*

Design Basis & Repair

FSAR Structural Design Parameters

- **Containment Design Features Remain Unchanged**
  - Prestressed concrete cylindrical wall (shell), shallow dome roof
  - Carbon steel liner serves as fission product barrier
  - Liner anchored to concrete

- **Containment Design Basis Maintained**
  - Leak-tight structure to contain Design Basis LOCA
  - Elastic response to design basis loading to protect liner
  - Design loads and combinations based on operating, accident and applicable code requirements
  - Load factors applied to provide safety margin

Design Basis Repair
FSAR Design Loads

- **All Containment Design Loads Analyzed**
  - Live, Prestress, Dead Loads
  - Wind
  - Tornado Wind
  - Tornado Pressure
  - Tornado Missiles
  - Seismic
  - Temperature Loads
  - Accident Pressure (LOCA)
  - Accidental Containment Spray Actuation Pressure

Design Basis & Repair
Summary

- **Final repair condition expected to be acceptable under 10 CFR 50.59**
  - Design basis loading conditions will be satisfied
  - Design code requirements will be met
  - Changes to analysis inputs accepted by 50.59 evaluation
  - Analysis consistent with the existing FSAR described Method of Evaluation

Design Basis & Repair
Repair Sequence

- **Stress Relief Cut** - *Complete*
- **De-tensioning** - *Complete*
- **Concrete Removal** - *Complete*
- **Concrete Placement** - *In Progress*
- **Re-tensioning**
- **Post-Repair Testing**
- **Unit Restart**

Post Repair Testing
Pressure Tests

- **Integrated Leak Rate Test (ILRT) required per ASME XI code**
  - For removing / replacing liner in SGR opening
- **Plan to perform a Structural Integrity Test (SIT)**
  - Normally a one-time initial construction structural test
  - Test intent: measures structural integrity and deformation at 1.15 Peak Design Pressure (63.3 psig)
  - SIT will be followed by ILRT

Summary

- Containment original design and construction are acceptable for normal and emergency operations
- Planned repair approach meets design basis requirements and code requirements
- The final repair condition is expected to be acceptable under 10 CFR 50.59
- Containment will be fully capable of meeting its design safety function upon completion of repairs and testing