Sengupta, Abhijit

From: Thomas, George
Sent: Thursday, November 19, 2009 11:28 AM
To: Carrion, Robert; Masters, Anthony; Farzam, Farhad; Ashar, Hansraj; Sheikh, Abdul
Cc: Khanna, Meena; Lake, Louis
Subject: Presentation made to PNSC
Attachments: 2009 Nov 16 - PNSC - Repair Update_FINAL.pptx 39 page

Attached FYI is the presentation Mr. Garry Miller (CR3 Containment Delam PM) made to the Plant Nuclear Safety Committee, which approved the recommendation made for repair as "Remove and replace delamination". Please do not distribute.

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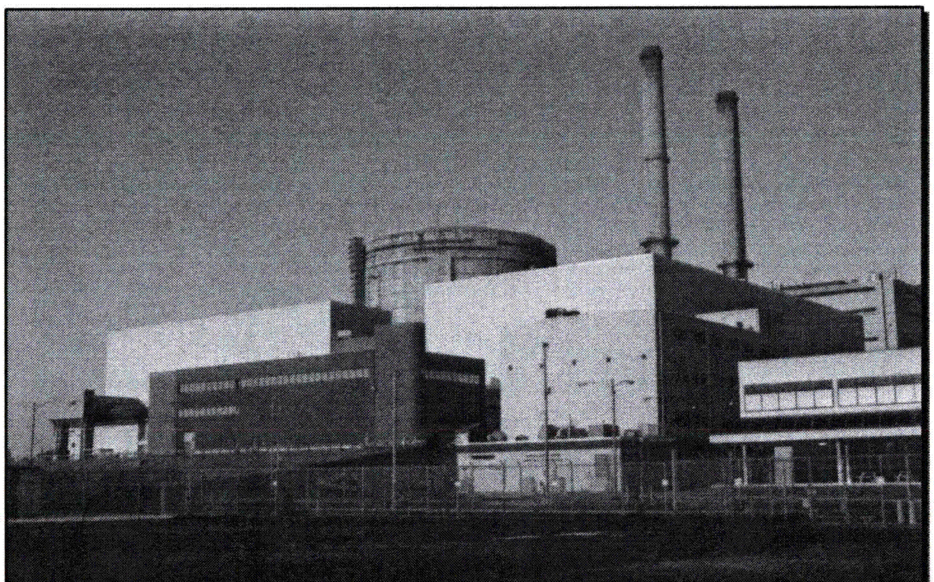
P/209

Crystal River Unit #3

Presentation to PNSC Containment Update & Discussion of Repair Options

November 16th 2009
Presented by Garry Miller



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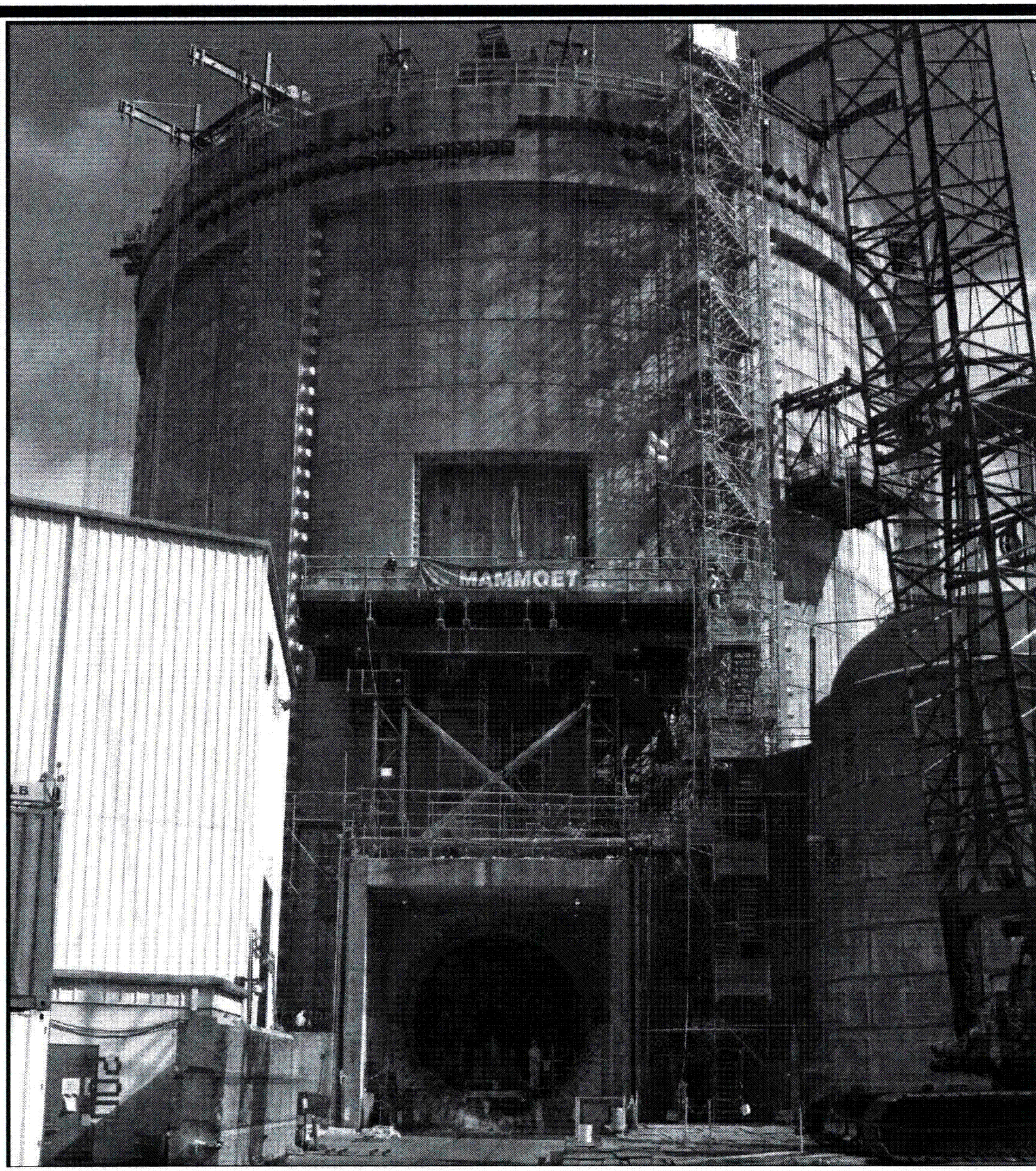
Steam Generator Replacement (SGR) Opening
(between Buttresses 3 and 4)



SGR Opening Dimensions

@ Liner
23' 6" x 24' 9"

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

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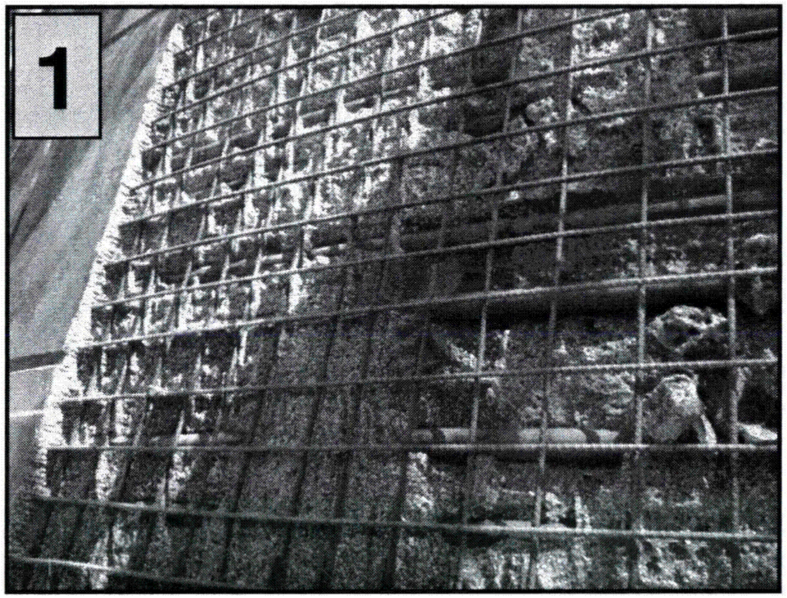
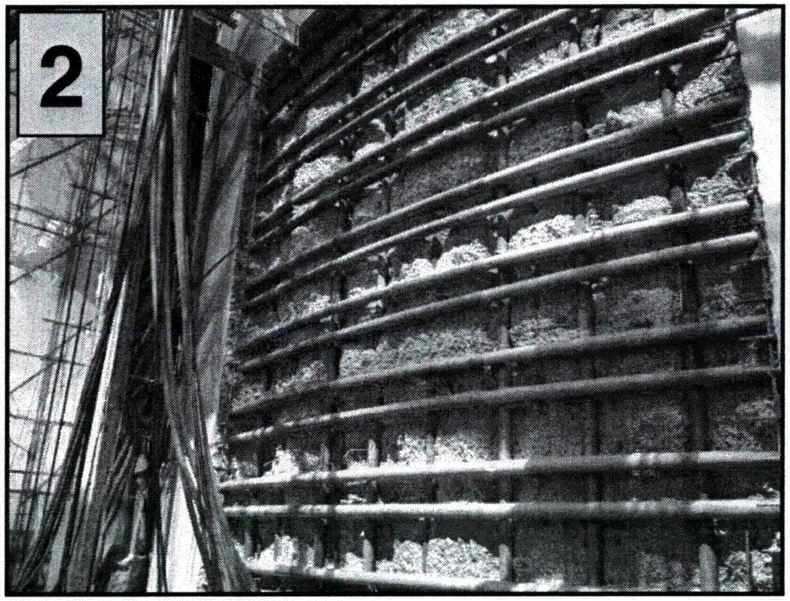
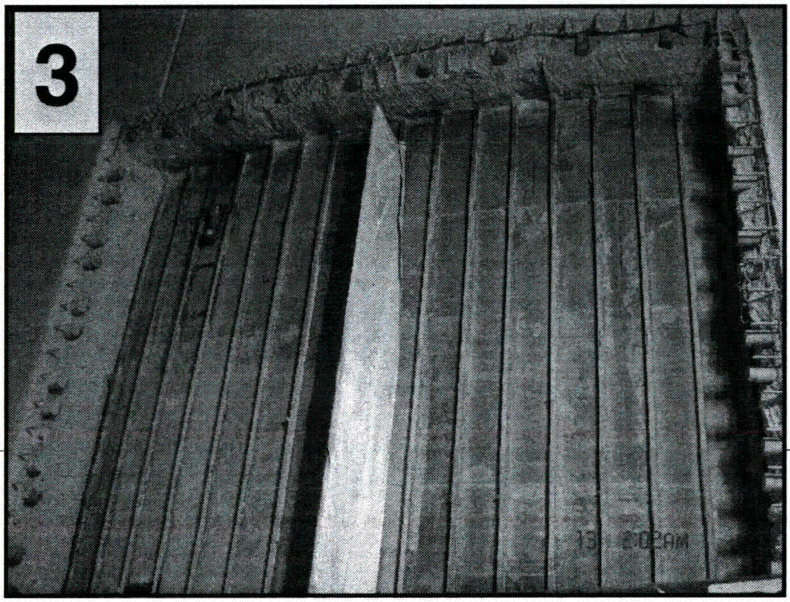
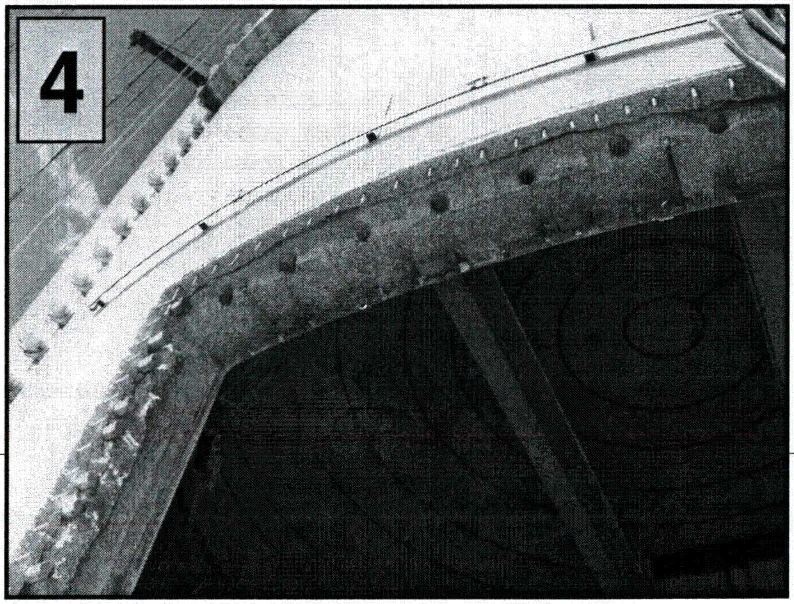
Hydro-Demolition & Liner Removal Sequence

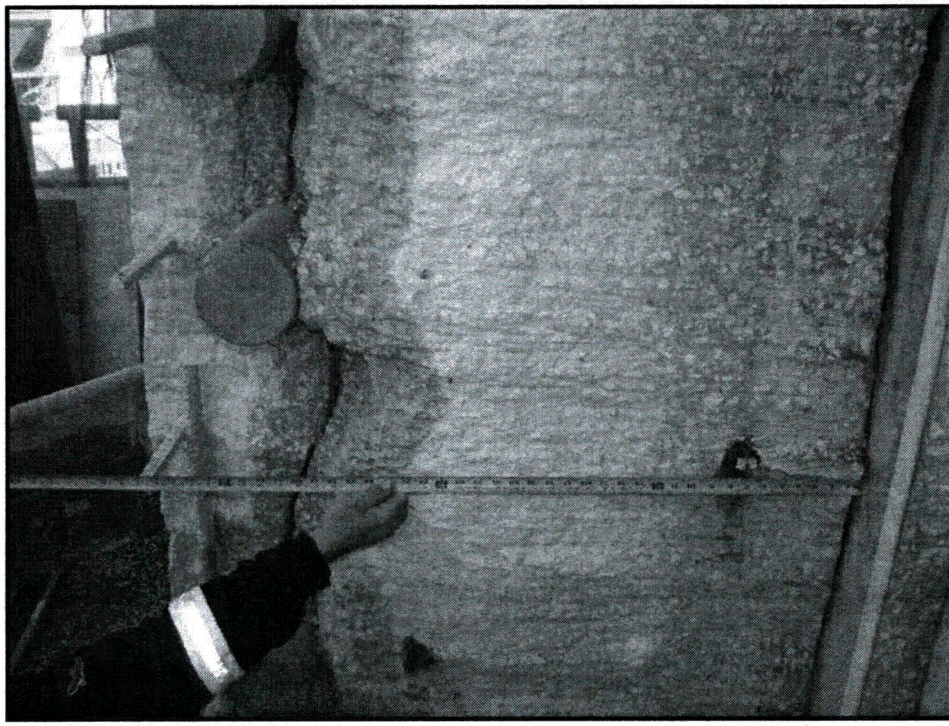








Delamination Close-up



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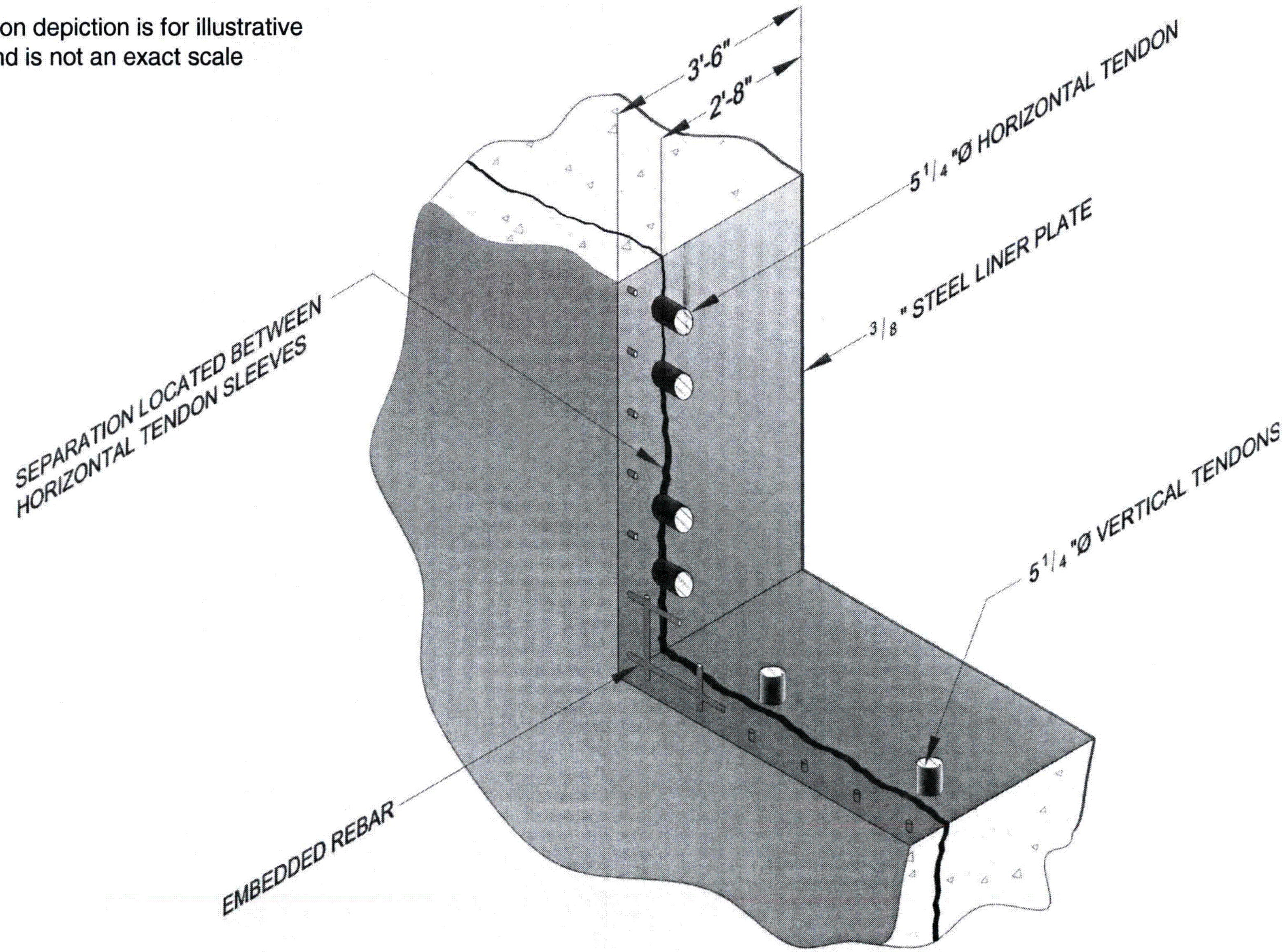
Location of the Delamination

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



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 area
  - Core bore samples in repaired and non-repaired areas
  - Physical survey (compared to 1976 results)

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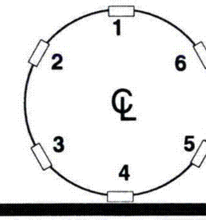
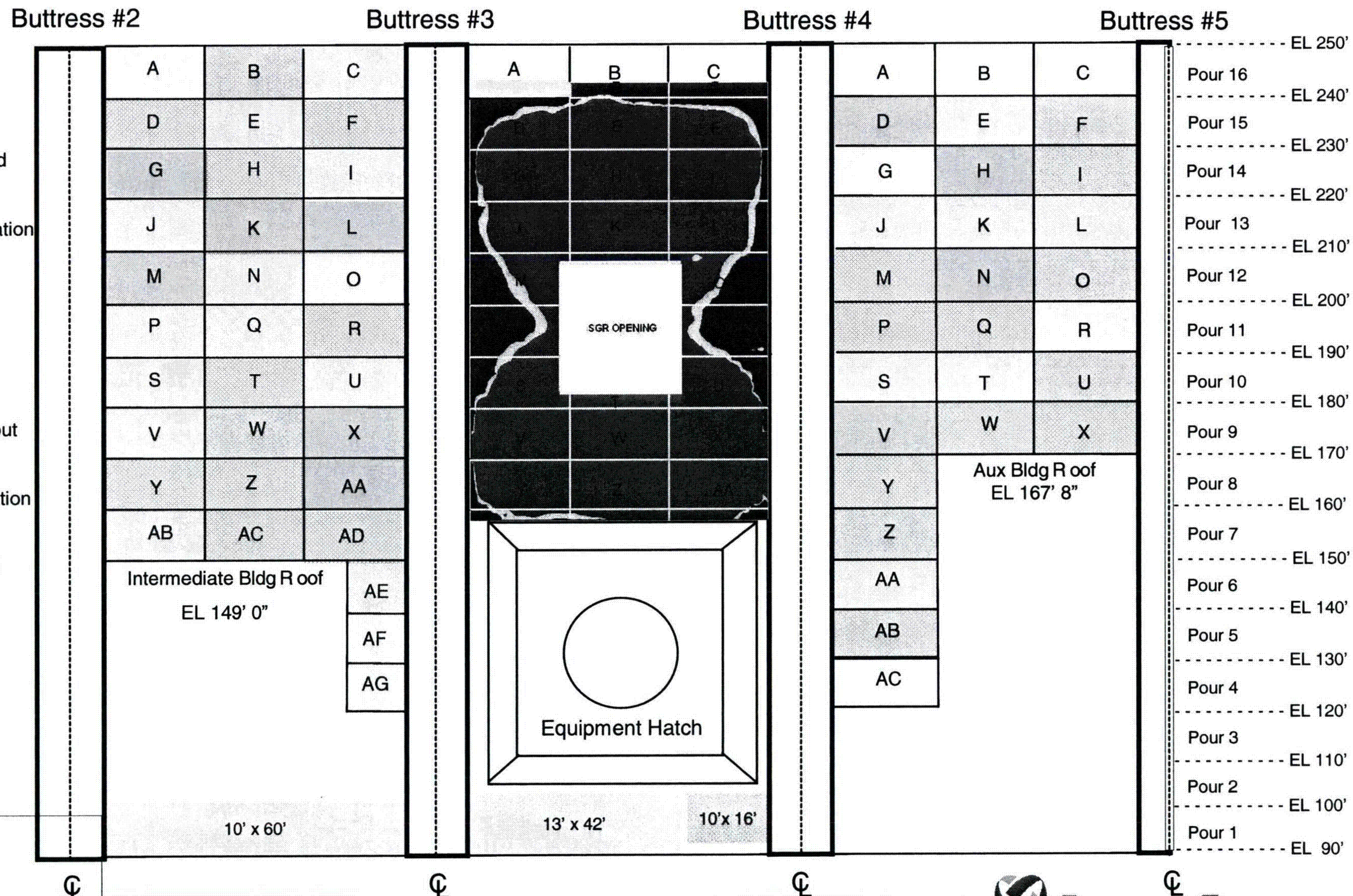
Containment "Unfolded" – Buttress 2 to 5

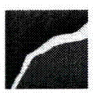
Updated Nov 16th , Mosaic IR Overlay scale is approximate





IR scans completed per PT-407T:

Blue = no delamination



Actual IR scan output data:

Blue = no delamination

Yellow= transition

Red = delaminated

Drawing scale is not exact

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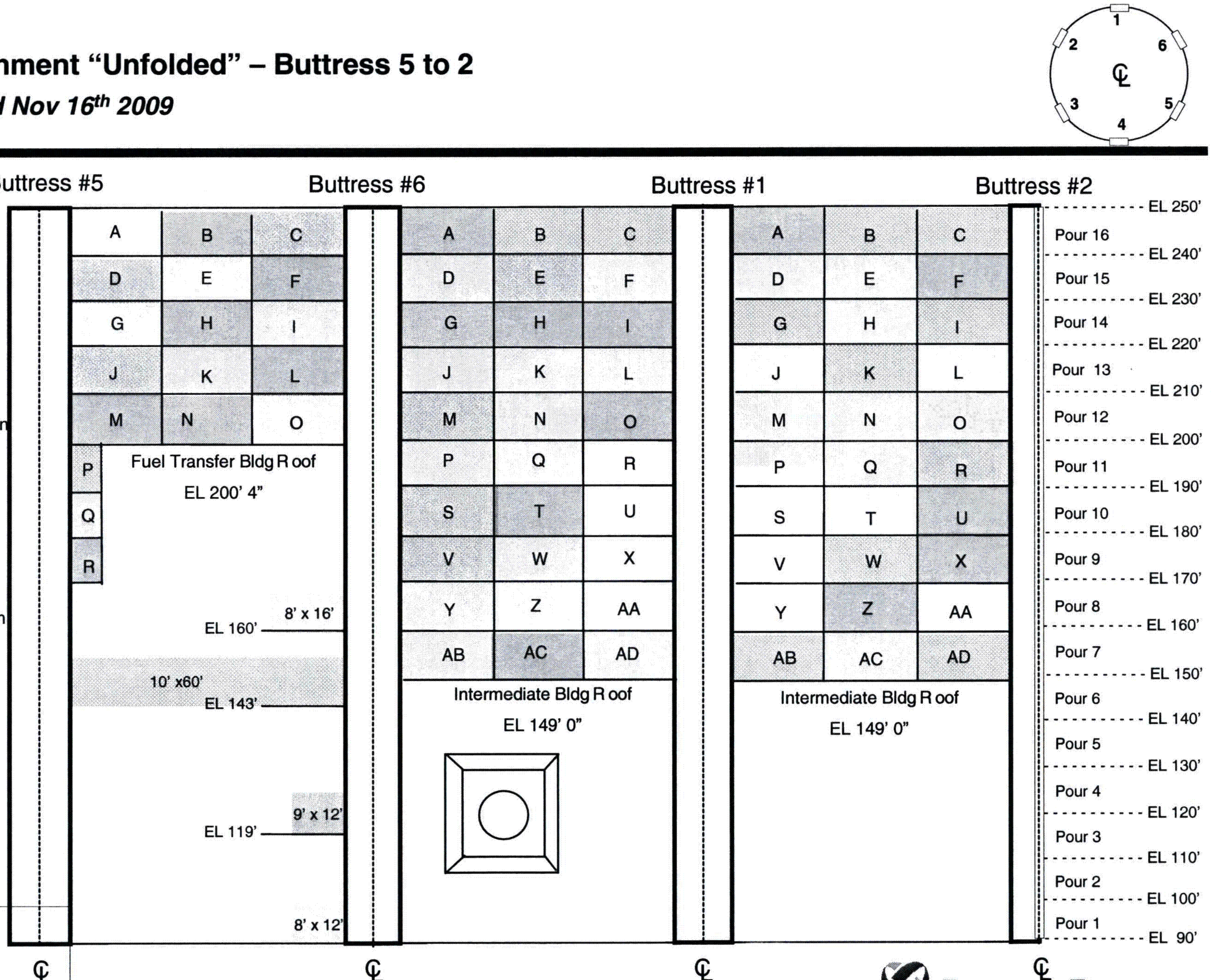
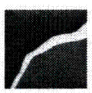
Containment "Unfolded" – Buttress 5 to 2

Updated Nov 16th 2009



IR scans completed per PT 407T:

Blue = no delamination



Actual IR scan output data:

Blue = no delamination

Yellow= transition

Red = delaminated

Drawing scale is not exact

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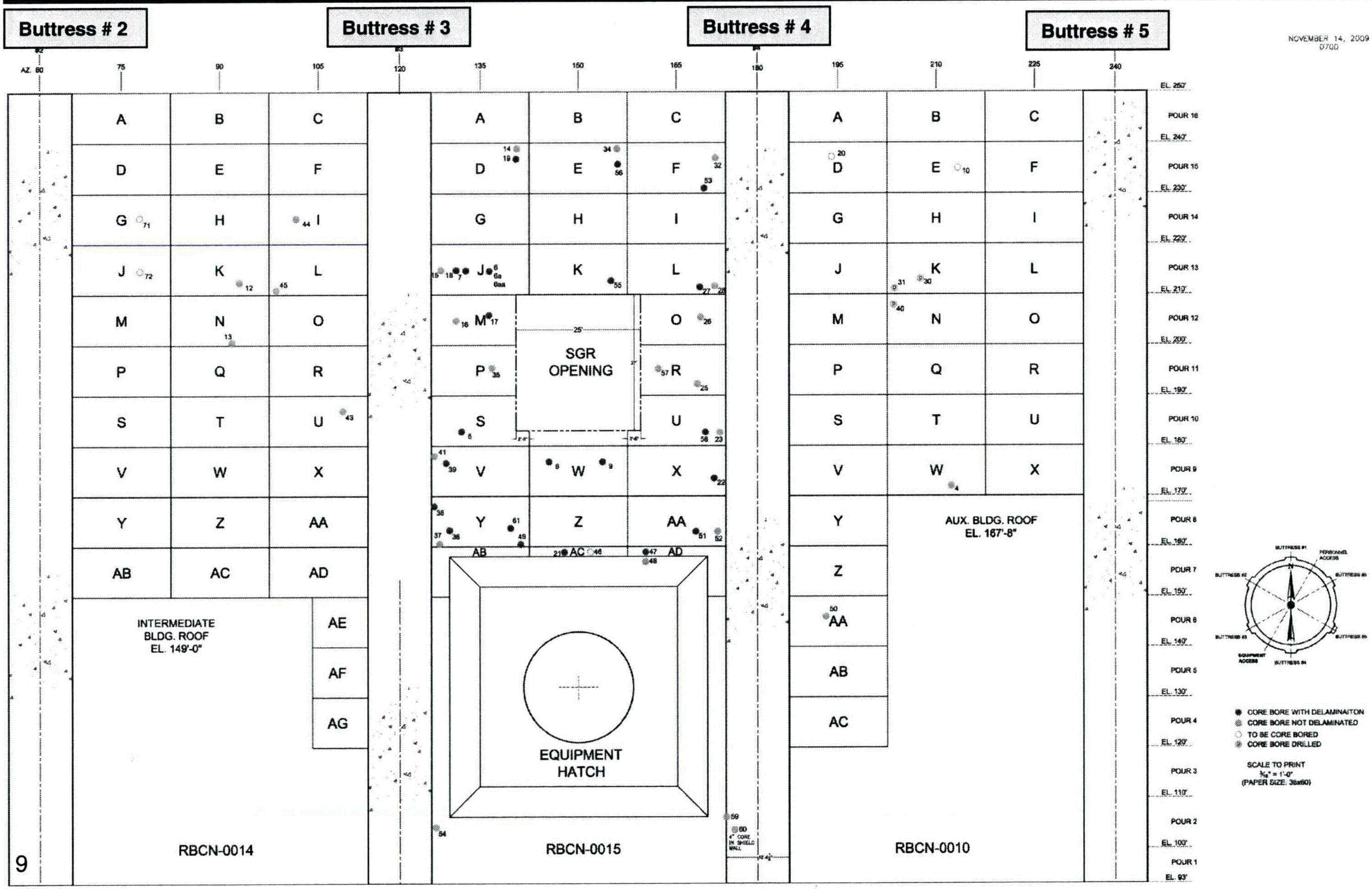
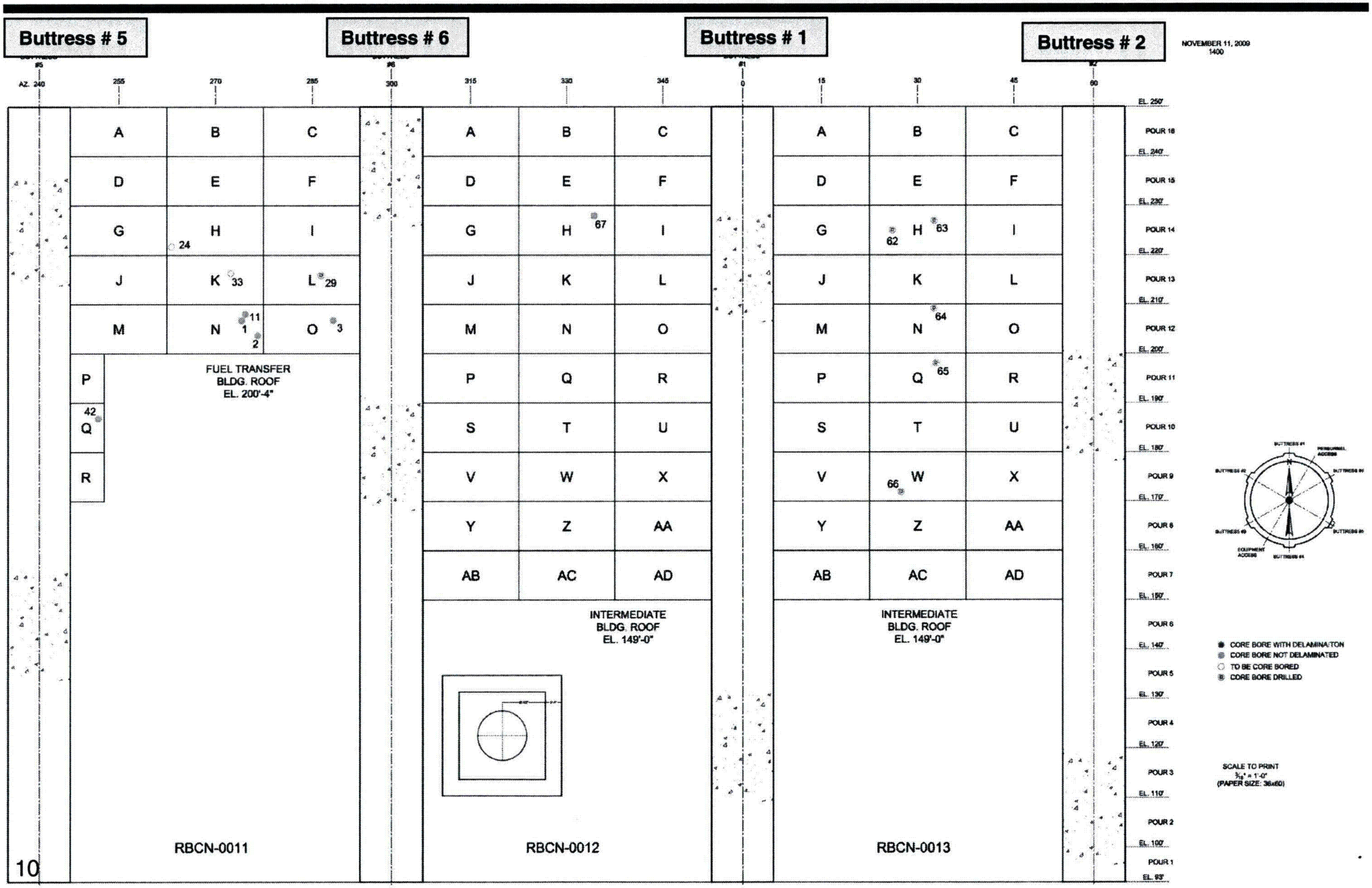
Core Bores

Buttress spans 2- 3- 4- 5 (as of Nov 14th 2009)

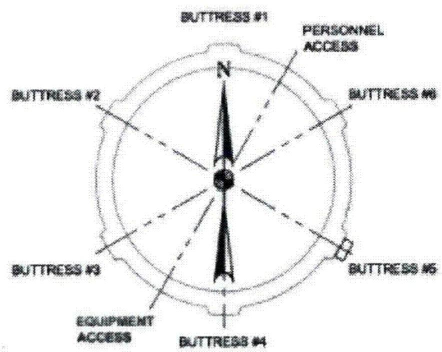


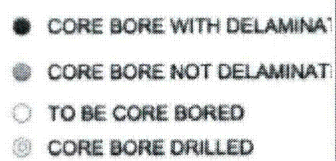
Core Bores

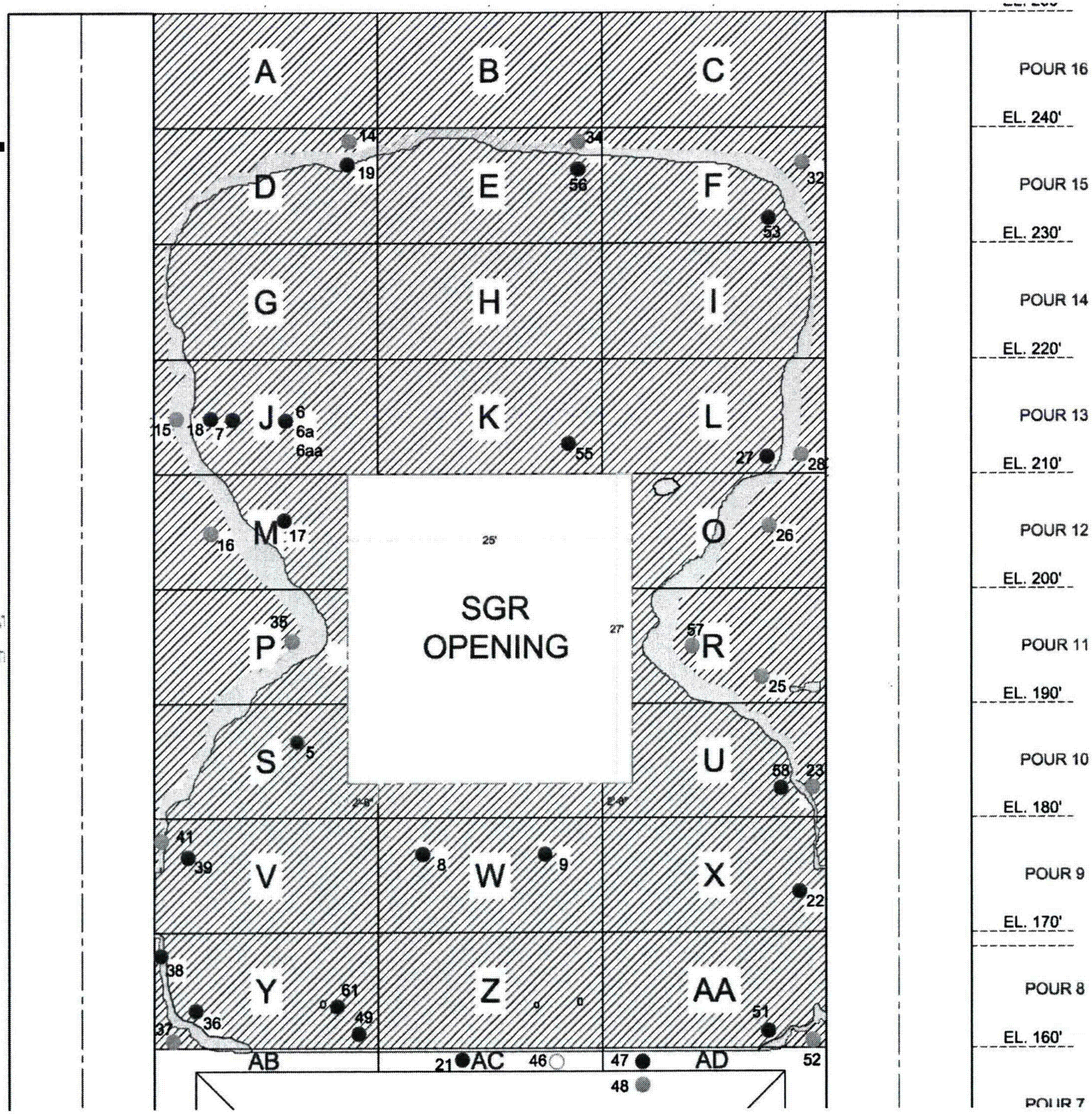
Buttress Spans 5 - 6 - 1 – 2 (as of Nov 14th 2009)



Core Borings





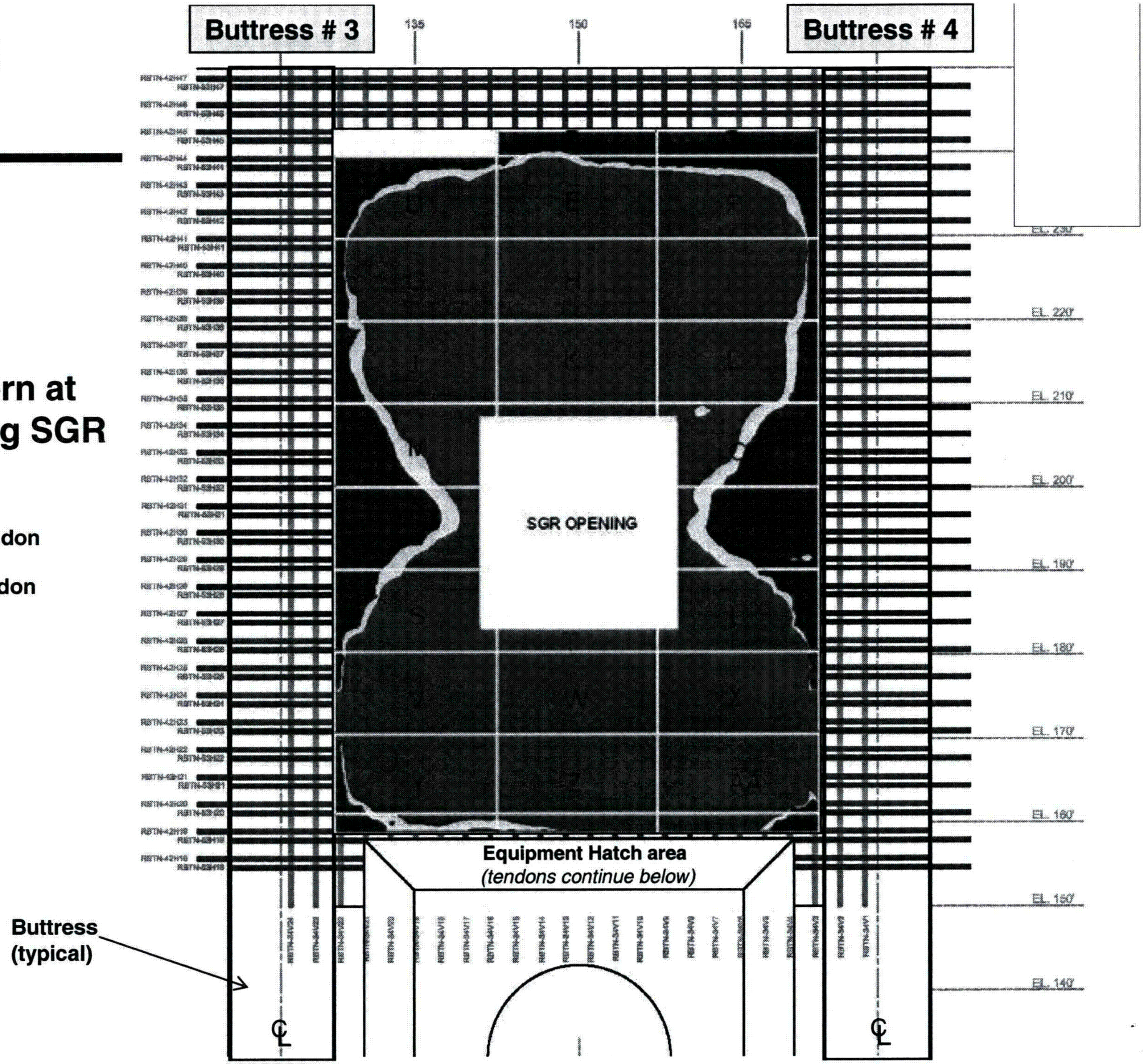


Tendon Pattern

Tendon Pattern at time of cutting SGR Opening

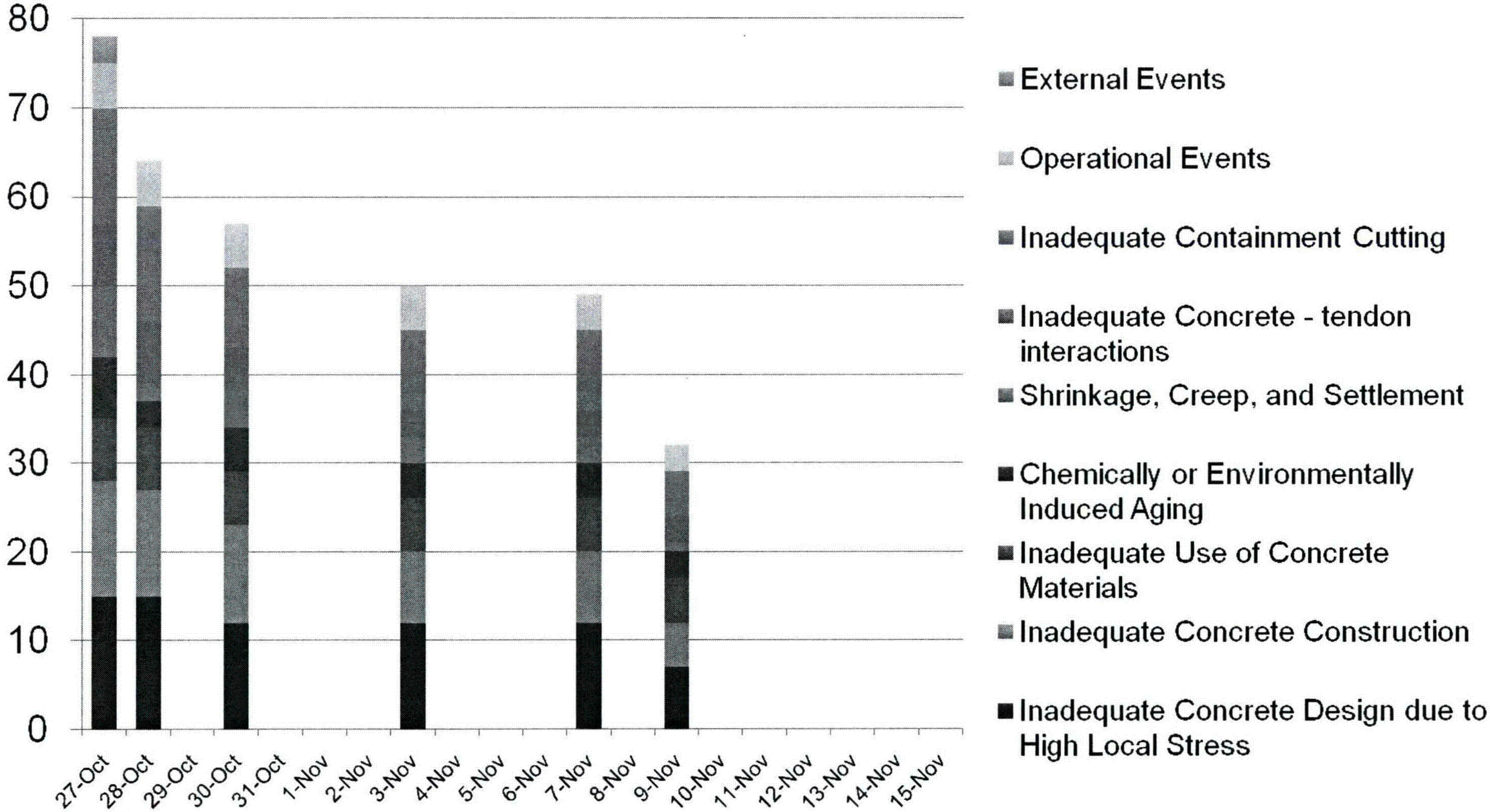
Energized Tendon

Removed Tendon



Root Cause Analysis – PII Metrics

Un-refuted Failure Modes as of Nov 9th 2009



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Root Cause Analysis
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

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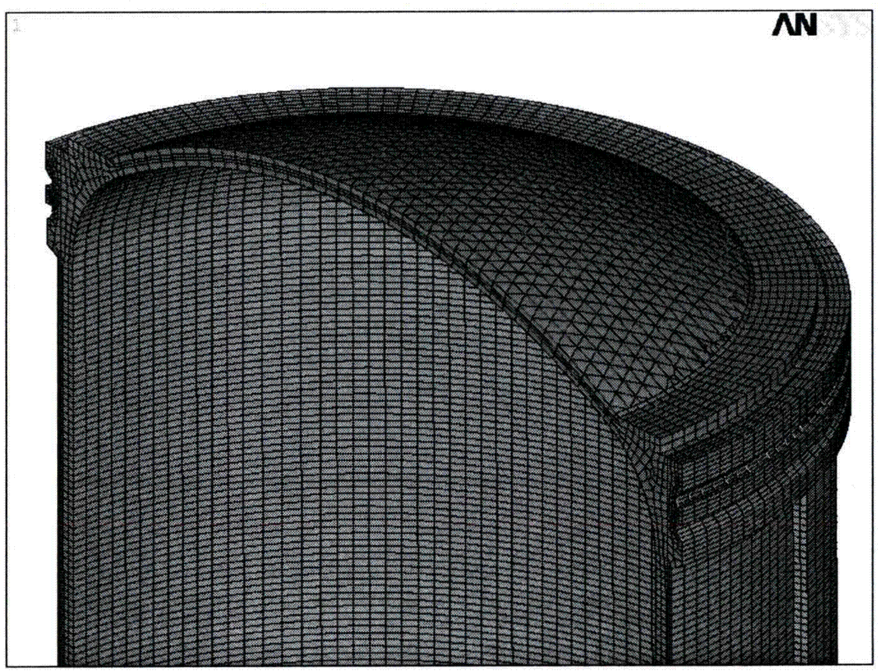
Root Cause Analysis
Field Data Acquisition (continued)

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

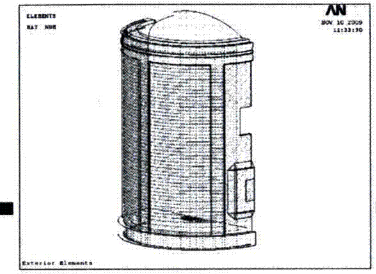
Root Cause Analysis
Field Data Acquisition (continued)

- 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

DESIGN BASIS ANALYSIS



MPR 3D FE Model
Model Features



- **180 degree Symmetric model**
  - Symmetry plane @ 150 degrees midway Between Buttress 3 & 4 / 1 & 6
  - ½ Opening, ½ Damage & ½ 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 Modeling**
  - 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

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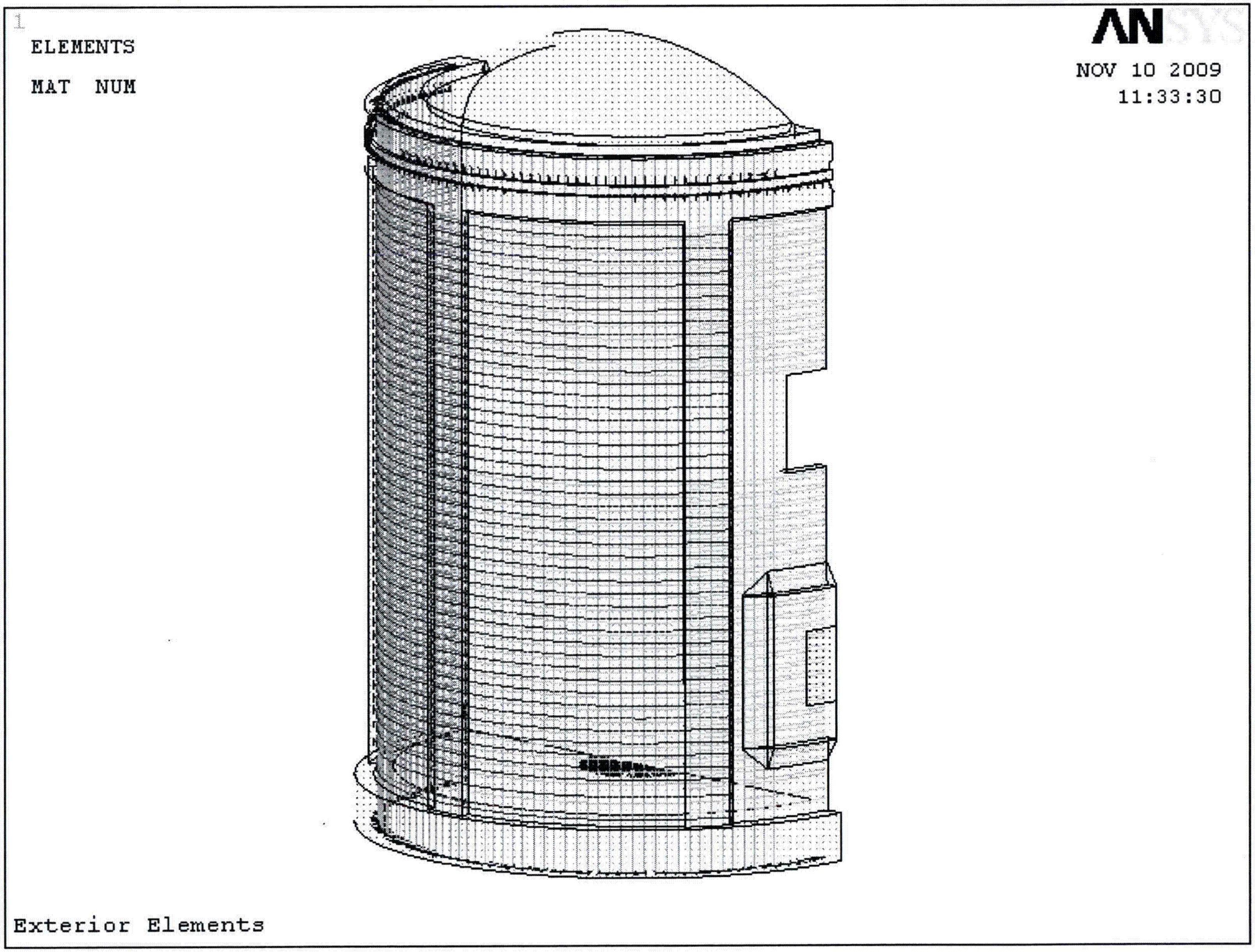
MPR 3D FE Model
Model Features (continued)



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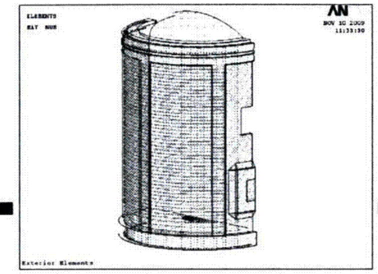
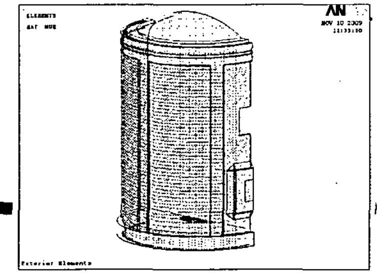
MPR 3D FE Model
Load Cases



- Live and Dead Loads
- Wind (110mph @ 30’ increasing to 179 mph @ 166’10”)
- Tornado Wind (300 mph)
- Tornado pressure (external pressure of 3 psig)
- Tornado Missiles (35’ utility pole or 1 ton car @ 150 mph)
- Seismic (OBE – 0.05 and SSE – 0.10)
- Temperature Loads
- Accident Pressure (55 psig)
- Accidental Containment Spray Actuation Press (-2.5 psig)

MPR 3D FE Model
Specific Analysis to be Performed



- **Existing Design Cases for Comparison**
  - Gravity (.95 G)
  - Internal Dead Load (200 puff)
  - Tendons (1635 kips / tendon)
    - Include losses
  - Internal Pressure (55.0 psi)
  - Wind Pressure (0.568 psi)
  - Seismic
  - Accident Thermal

- **Planned Analysis Sequence**
  - Dead Load + Tendons
  - Remove Hoop + Vertical Tendons in SGR Opening
  - Remove SGR Opening
  - Delamination[1]
  - Remove Additional Hoop & Vertical Tendons
  - Replace the SGR Plug[2]
  - Repair[2]
  - Re-tension Tendons
  - SAVE Path Dependent Model for Starting point to Run 5 Controlling Design cases

[1] Root cause must confirm delamination timing
[2] Sequence of replacing SGR concrete plug or repair may be adjusted

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Repair Attributes

- Incorporates and is compatible with Root Cause Analysis findings
- Restores applicable design basis margins

Design Basis Controlling Load Steps

- Incorporates Life of Plant Considerations
  - Long Term Surveillance and/or Maintenance Requirements
  - License Renewal
- Constructability

Repair Alternatives Considered

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

Repair Alternatives
"Use-as-Is" and "Anchorage Only"

- **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"

- **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

Repair Alternatives
"Cementitious Grout"

- **Cementitious Grout** – *Rejected (continued)*
  - Mock-up test needed to validate tendon duct integrity (leak tightness against grouting injection)
    - Test may indicate leak tightness is not assured
  - Requires anchorage to resist grout injection pressures(≥20 psig), and this has all of the same difficulties as detailed in the "Anchorage Only" repair
    - This anchorage system limits access to effectively perform IR scans to ensure complete grout coverage
  - Physical properties of grout would require detailed evaluation and/or verification to prior to use
    - Many grouts are blended for geotechnical applications
    - Tensile strength of typical grouts is significantly lower than epoxy resins

Repair Alternatives
"Epoxy Resin"

- **Epoxy Resins** - *Rejected*
  - Not viable in gaps greater than ¼" 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

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Repair Alternatives
"Epoxy Resin"

- **Epoxy Resins** – *Rejected (continued)*
  - 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
  - Requires anchorage to resist epoxy injection pressures (8 to 20 psig), and this has all of the same difficulties as detailed in the "Anchorage Only" repair
    - This anchorage system limits access to effectively perform IR scans to ensure complete coverage

Repair Alternatives
Repair and Replacement

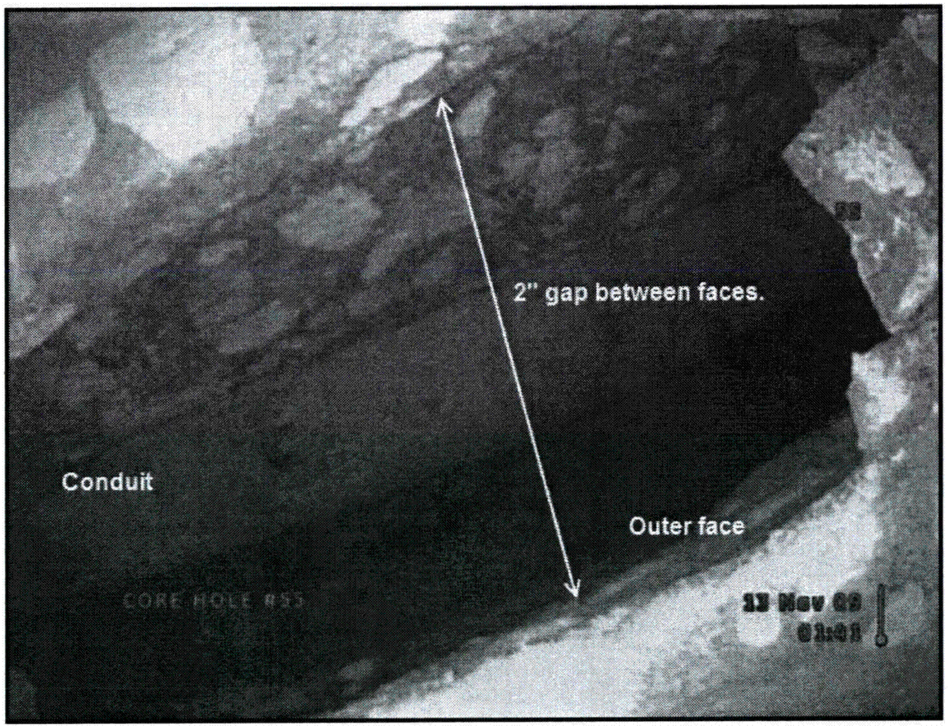
- **Delamination Removal and Replacement** – *Selected*
  - Delamination Removal Challenges
    - Safe removal of delaminated concrete at elevated heights
    - Avoiding collateral damage to tendon conduits
    - Minimize damage to the remaining substrate to minimize concrete bruising and to provide 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 Alternatives

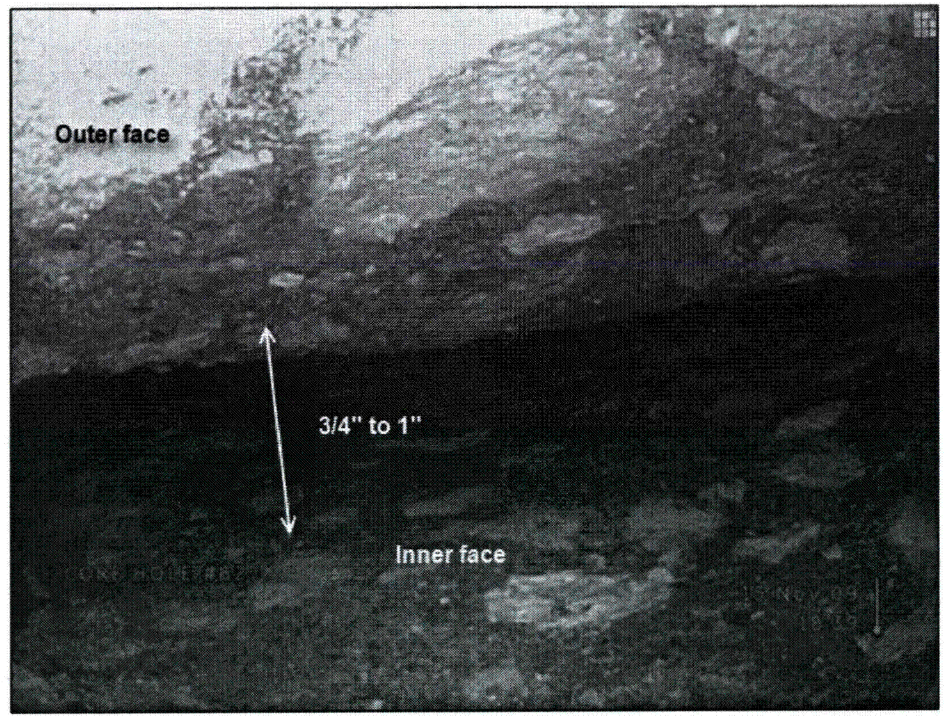
Repair and Replacement

- **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

Boroscopic Photos
Delamination Gap Dimensions



Buttress 3-4, Cell K, Core #55



Buttress 3-4, Cell H, Core #82

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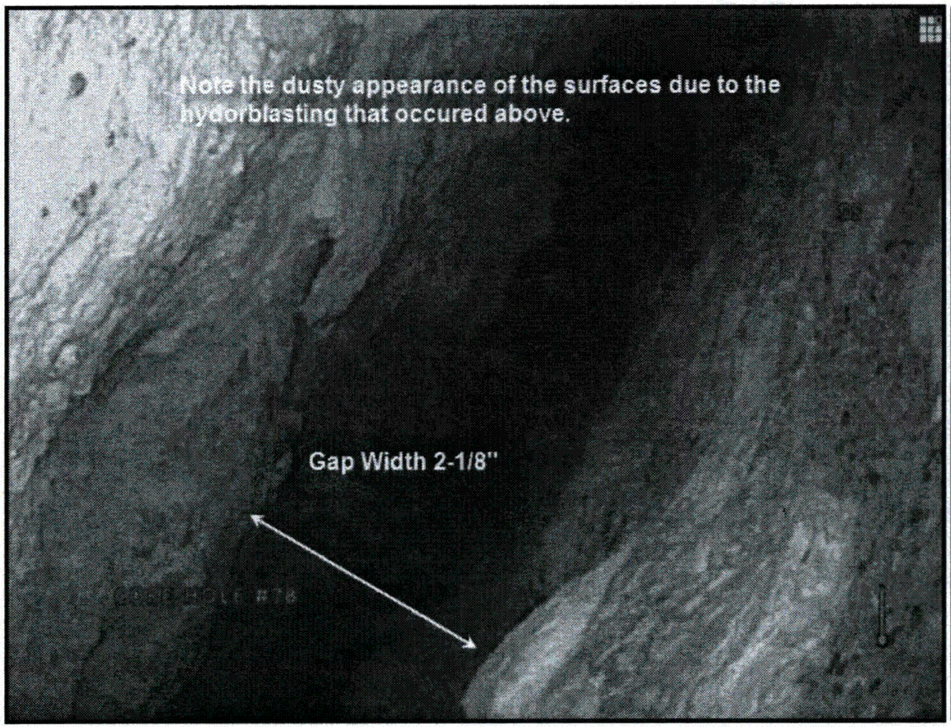
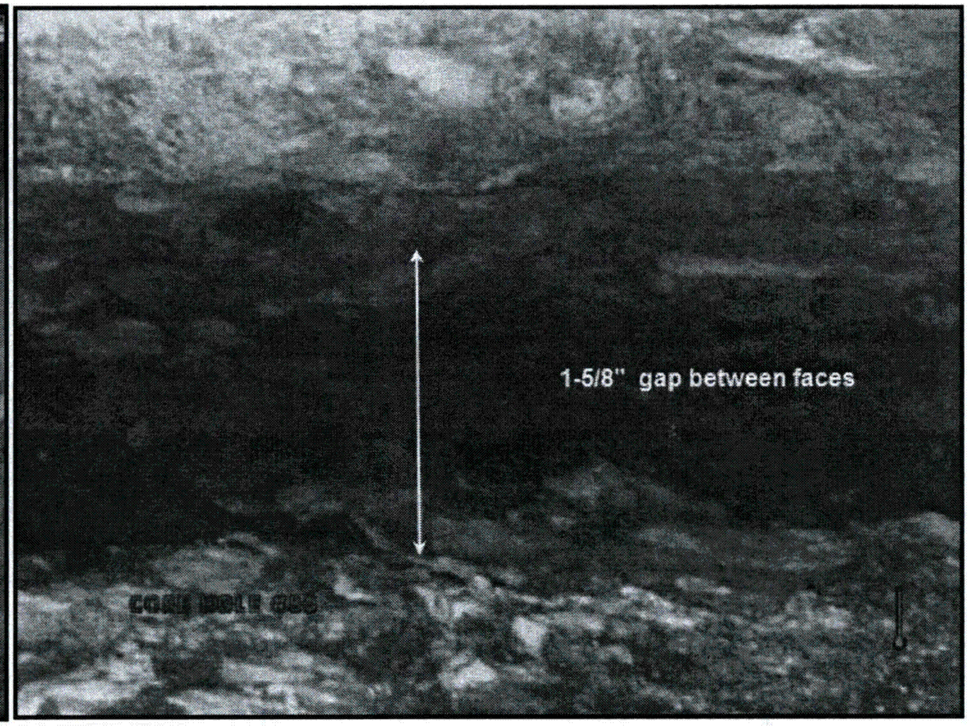
Boroscopic Photos
Delamination Gap Dimensions



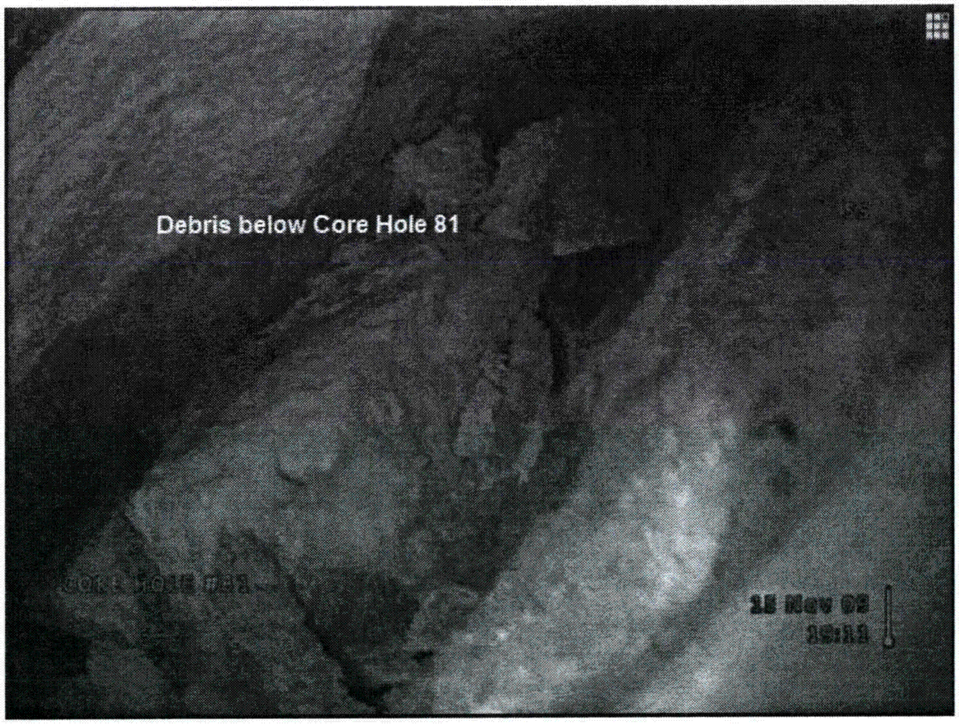
Buttress 3-4, Cell Z, Core #78



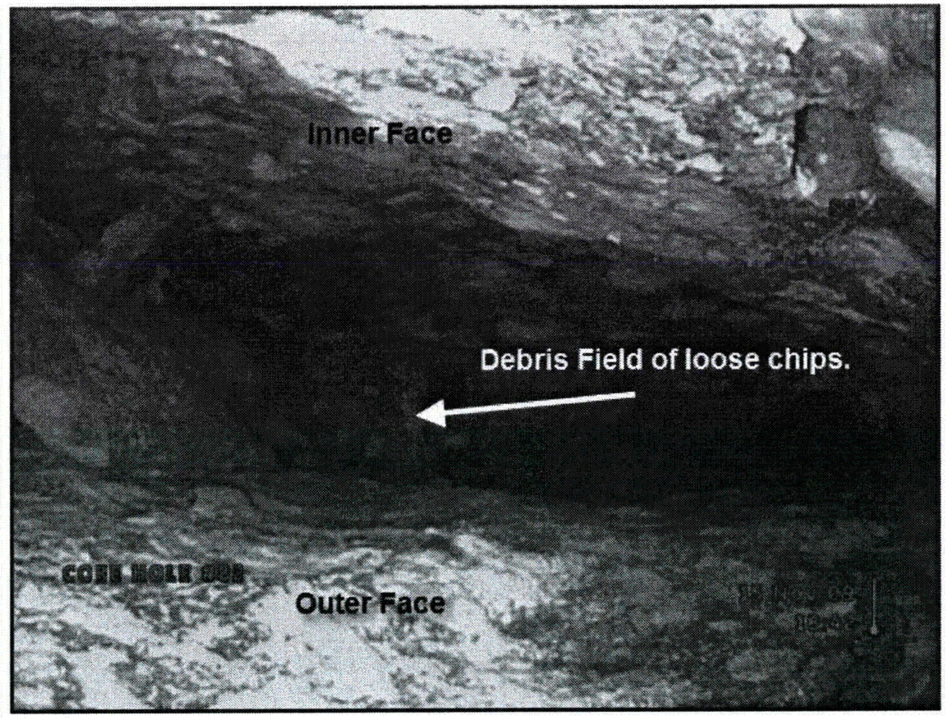
Buttress 3-4, Cell X, Core # 80

Boroscopic Photos

Debris in the Delamination Gap

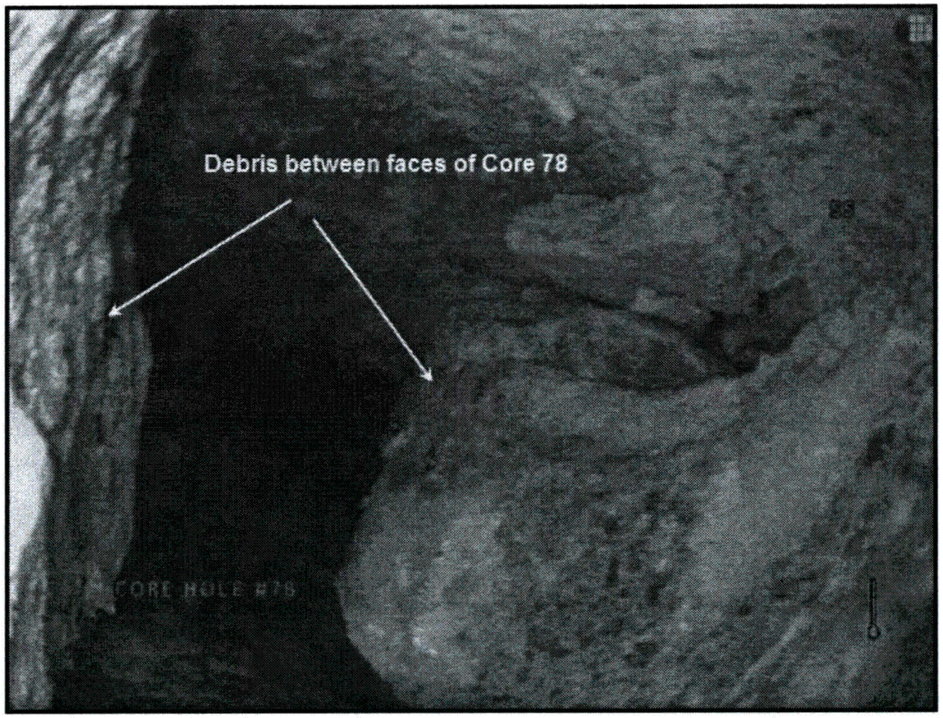


Buttress 3-4, Cell H, Core #81

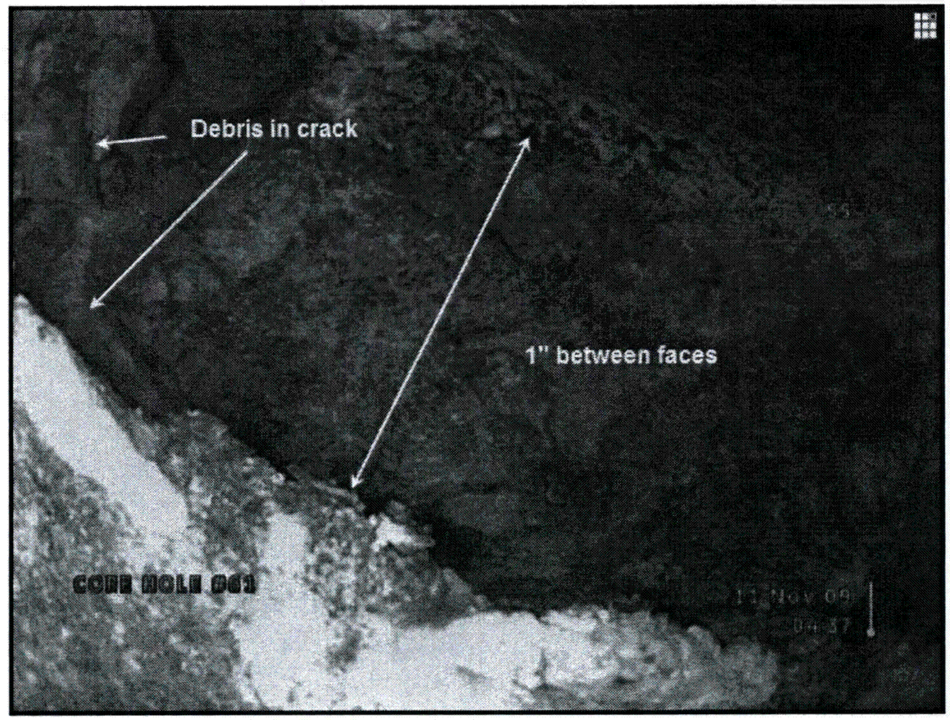


Buttress 3-4, Cell H, Core #82

Boroscopic Photos
Debris in the Delamination Gap



Buttress 3-4, Cell Z, Core # 78



Buttress 3-4, Cell Y, Core # 61

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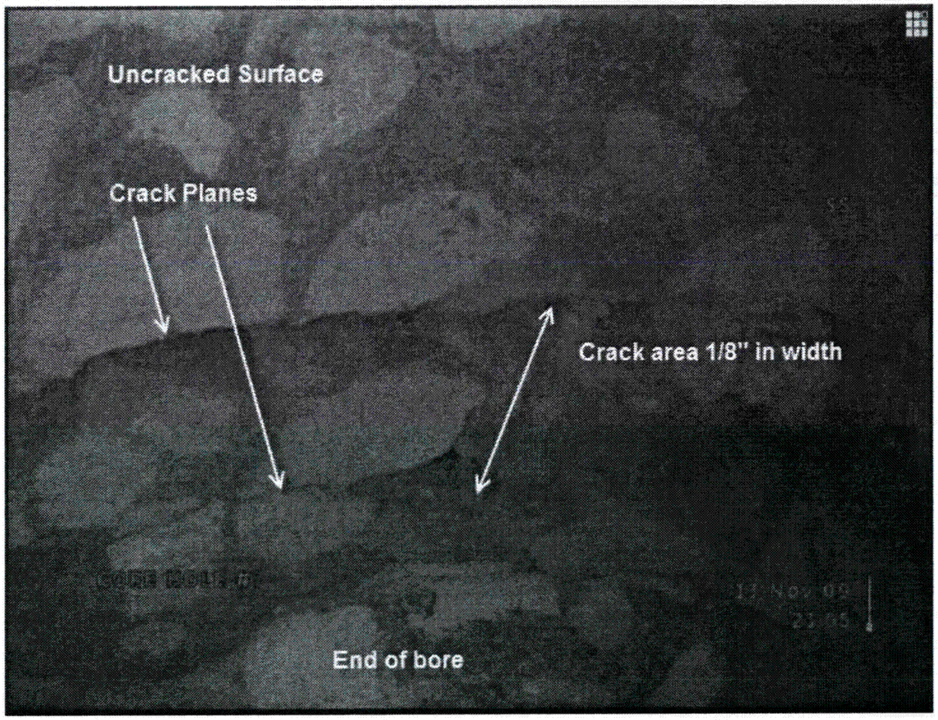
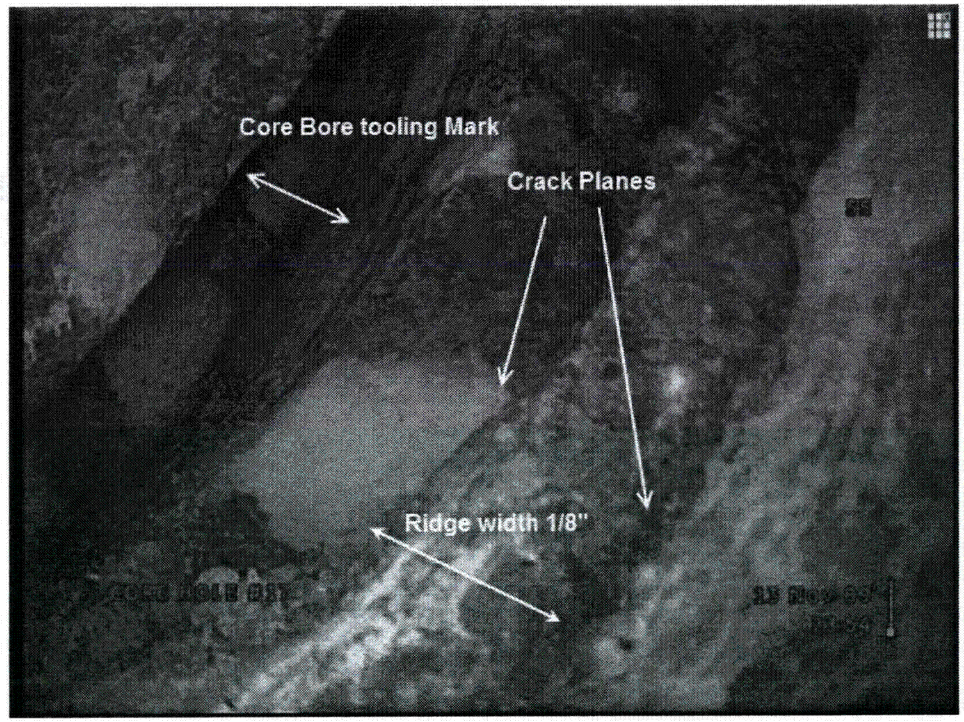
Boroscopic Photos
Fissures in the Delamination Gap



Buttress 3-4, Cell J, Core #7



Buttress 3-4, Cell M, Core #17

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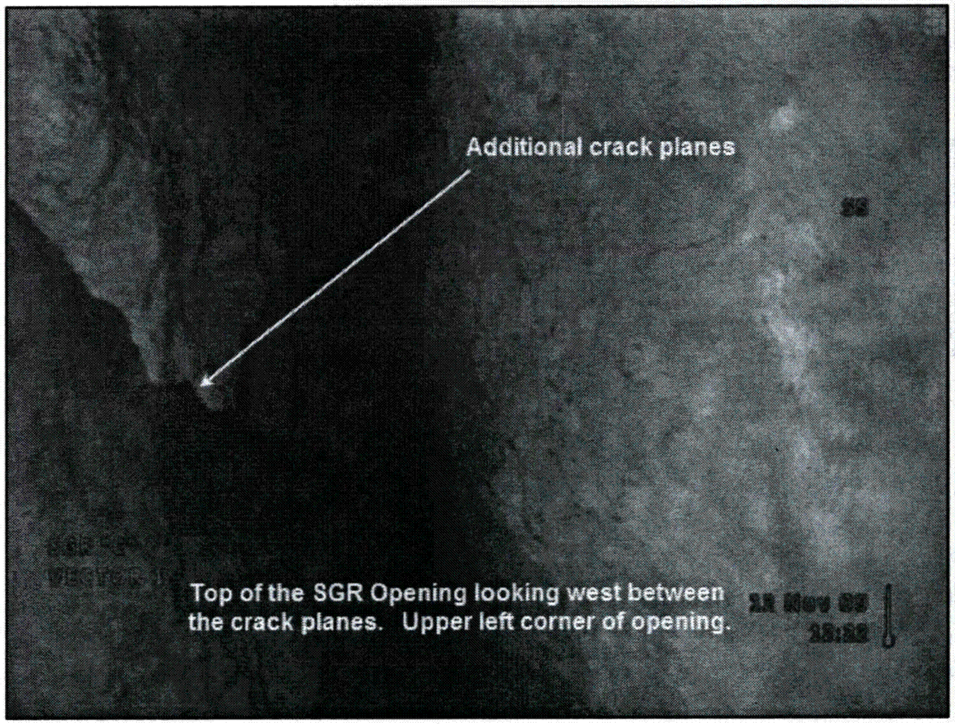
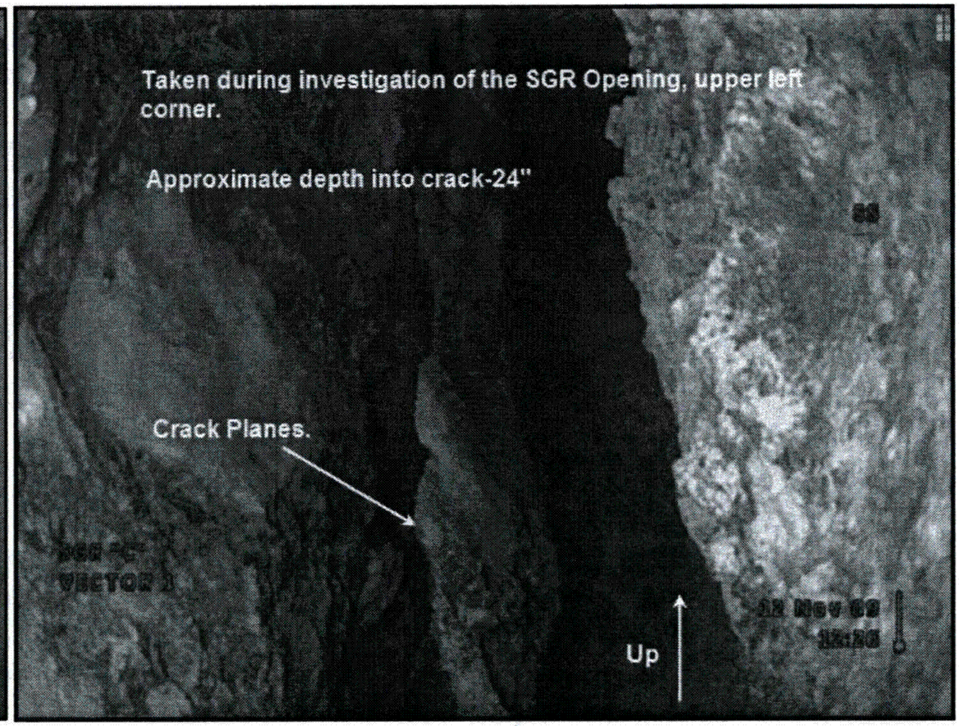
Boroscopic Photos
Fissures in the Delamination Gap



Buttress 3-4, Top of SGR Opening
Upper Left Corner, Looking West



Buttress 3-4, Top of SGR Opening
Upper Left Corner

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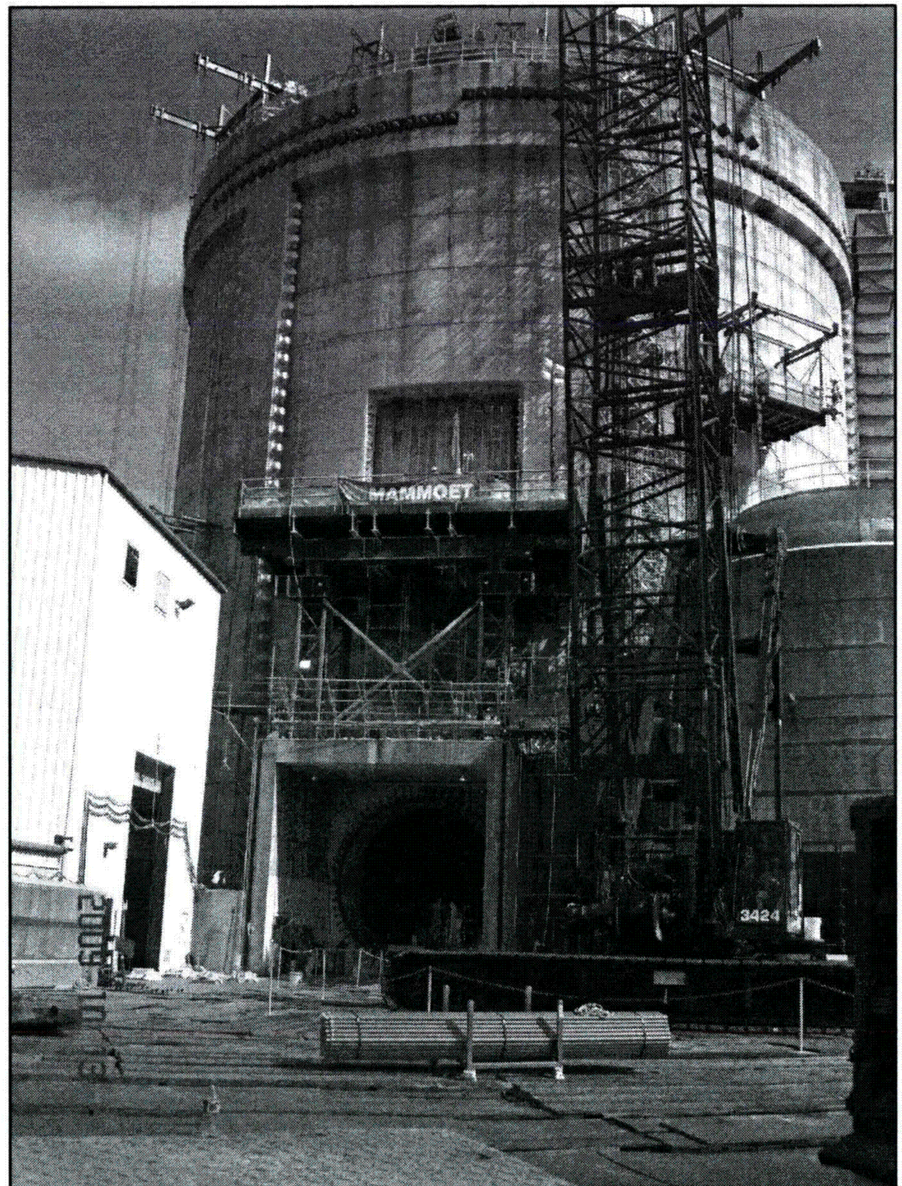
Summary & Questions

Questions



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