5/1/15

Masters, Anthony

From: Thomas, George
Sent: Thursday, November 19, 2009 8:10 AM
To: Carrion, Robert; Masters, Anthony; nausdj@ornl.com
Subject: FW: CR3 Draft Nov 20 Presentation
Attachments: 2009 Nov 17 - Advanced Draft for NRC - NRC Nov 20 Technical Mtg.pdf

Categories: Perform Review

Draft slides for Friday public meeting FYI. final slides will be available later today.

From: Khanna, Meena
Sent: Wednesday, November 18, 2009 11:37 AM
To: Farzam, Farhad; Thomas, George; Manoly, Kamal; Sheikh, Abdul; Ashar, Hansraj
Subject: FW: CR3 Draft Nov 20 Presentation

draft slides for Friday's meeting...

From: Saba, Farideh
Sent: Wednesday, November 18, 2009 11:29 AM
To: Khanna, Meena
Subject: FW: CR3 Draft Nov 20 Presentation

Farideh E. Saba, P.E.
Senior Project Manager
NRC/ADRO/NRR/DORL
301-415-1447
Mail Stop O-8G9A
Farideh.Saba@NRC.GOV

From: Lake, Louis
Sent: Wednesday, November 18, 2009 6:47 AM
To: Saba, Farideh
Cc: Franke, Mark; Kennedy, Kriss; Sykes, Marvin; Reyes, Luis; Wert, Leonard; Reyes, Rogerio
Subject: RE: CR3 Draft Nov 20 Presentation

Attached is the draft presentation that Garry gave me last night. He cautioned me that there may be changes before the public meeting on Friday . Note that thay have already identified that there has been a change in the repair they are considereing. The PNSC met yesterday and recommended that the repair consist of the delamination removal and replacement.

Lou lake
SIT Lead

From: Saba, Farideh
Sent: Tuesday, November 17, 2009 3:08 PM
To: Franke, Mark; Higgins, Patrick; Lake, Louis
Subject: FW: CR3 Draft Nov 20 Presentation

Louis,

Q 20

Please let me know where you have saved the PE's draft presentation.

Regards.

Farideh

Farideh E. Saba, P.E.
Senior Project Manager
NRC/ADRO/NRR/DORL
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Mail Stop O-8G9A
Farideh.Saba@NRC.GOV

From: McCabe, Brian [mailto:Brian.McCabe@pgnmail.com]
Sent: Tuesday, November 17, 2009 2:47 PM
To: Wert, Leonard; Sykes, Marvin; Kennedy, Kriss
Cc: Saba, Farideh; Orf, Tracy
Subject: CR3 Draft Nov 20 Presentation

Marvin

Per our discussion, our draft presentation for the meeting on the 20th has been provided electronically to the SIT Lead, Lou Lake. Thus, the Region and NRR/RES should have access to the draft presentation once Lou puts it on an NRC shared drive. It is simply too big a file to email to you.

As we discussed, the presentation will likely change as we get closer to Friday and we progress further with our investigation/analyses, but the draft provided to Lou is a good foundation of what we will present on Friday.

Hope this helps.

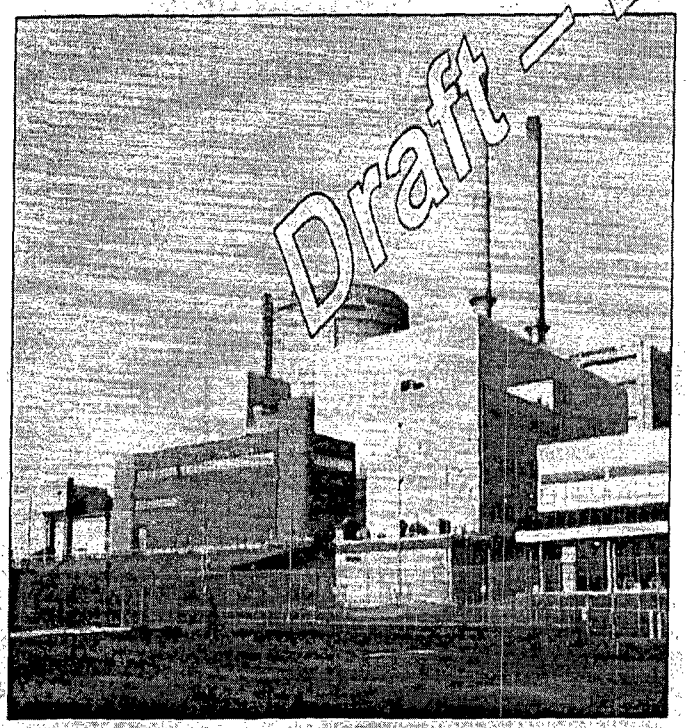
Brian

DRAFT

Crystal River Unit #3
Containment Delamination Update

Draft - Draft - Draft

November 6th 2009



Draft as of 11/17/2009 1:14 PM

Progress Energy

Agenda

DRAFT

- Introduction
- Plant Overview
- CR3 Containment Design Features
- SGR Opening Sequence & Identification of Delamination
- Investigative Approach
- Condition Assessment
- Root Cause Analysis (RCA)
- Operational Experience (OE)
- Design Basis Analysis (DBA)
- Repair Approach
- Summary Comments / Questions

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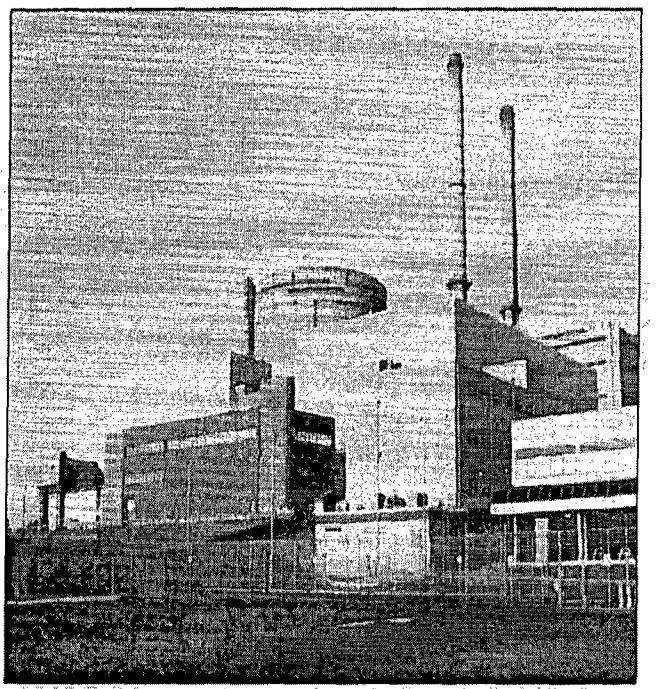
Crystal River 3 Overview

- Babcock and Wilcox Pressurized Water Reactor
- Location: Crystal River Florida
- 2609 MW_{th}
- 838 MW_e
- Commercial Operations began 1976



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2009 Crystal River 3 Outage Overview

DRAFT

Building a nuclear future for Florida customers

- **Routine refueling scope**
  - Off line maintenance and fuel for 2 years
- **Steam Generator Replacement (SGR)**
- **Extended Power Uprate (EPU)** – Phase 2
  - Extensive steam plant work
  - Taking advantage of longer OTSGR duration
  - Steam plant efficiencies
  - Part of total ~15% Uprate

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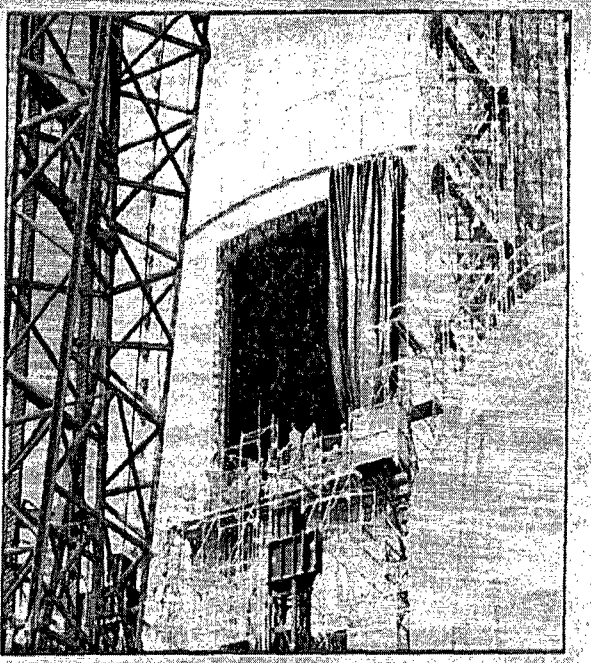
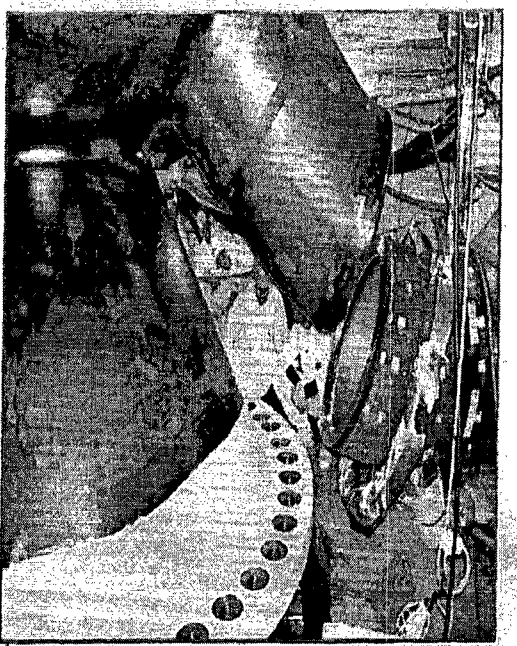
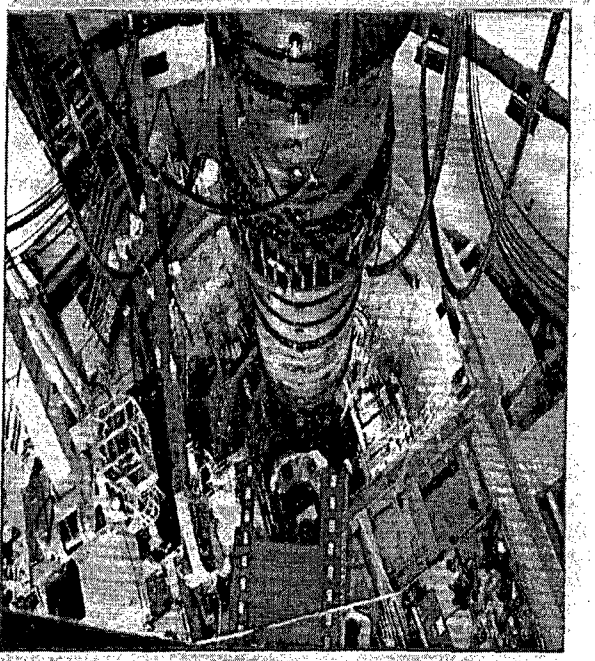
Steam Generator Replacement (SGR)
Work Breakdown

DRAFT

- Containment Opening
- Lifting and Rigging
- Cutting and welding







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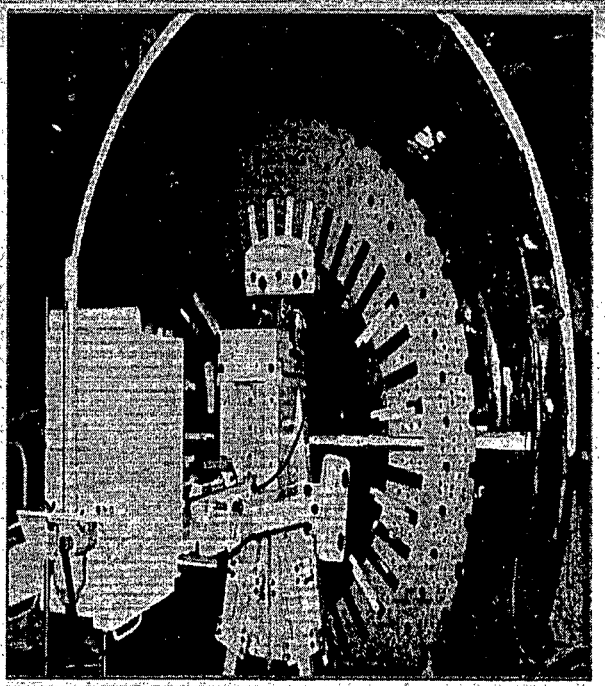
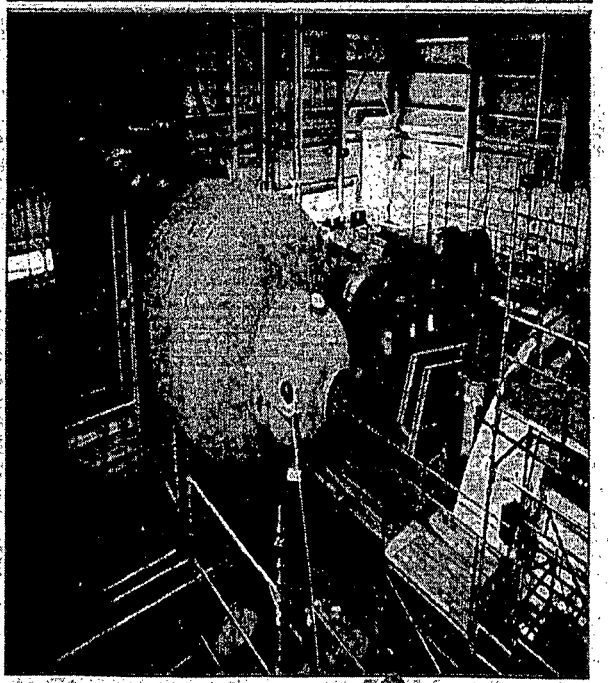
Extended Power Uprate (EPU)
Work Breakdown

DRAFT

- Generator Replacement
  - Stator, Rotor, Exciter
- Moisture Separators
- MSR Drain Coolers
- Lube Oil Coolers
- Feed Water Heaters
- Iso-Phase cooling





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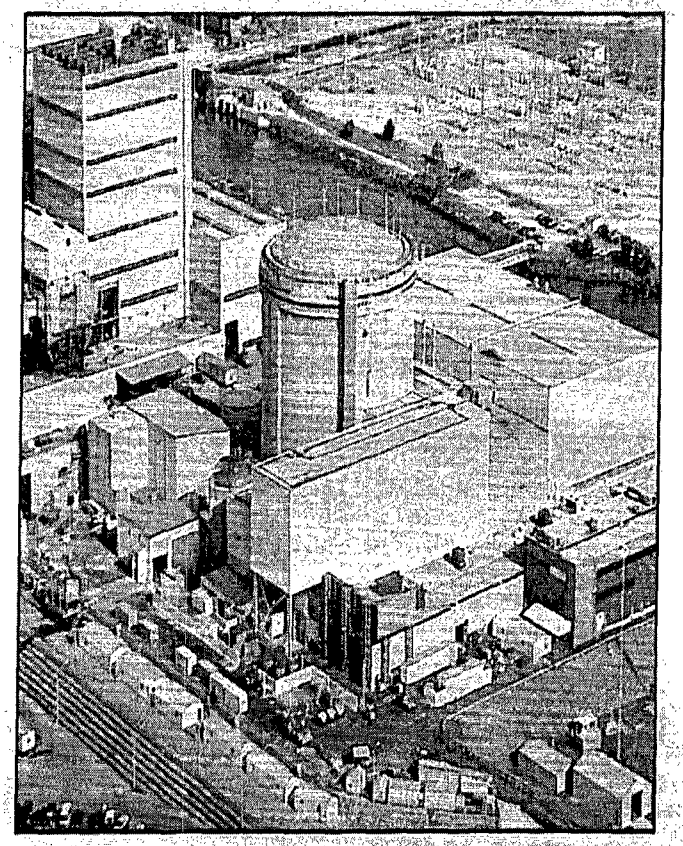
CRYSTAL RIVER #3
DESIGN FEATURES



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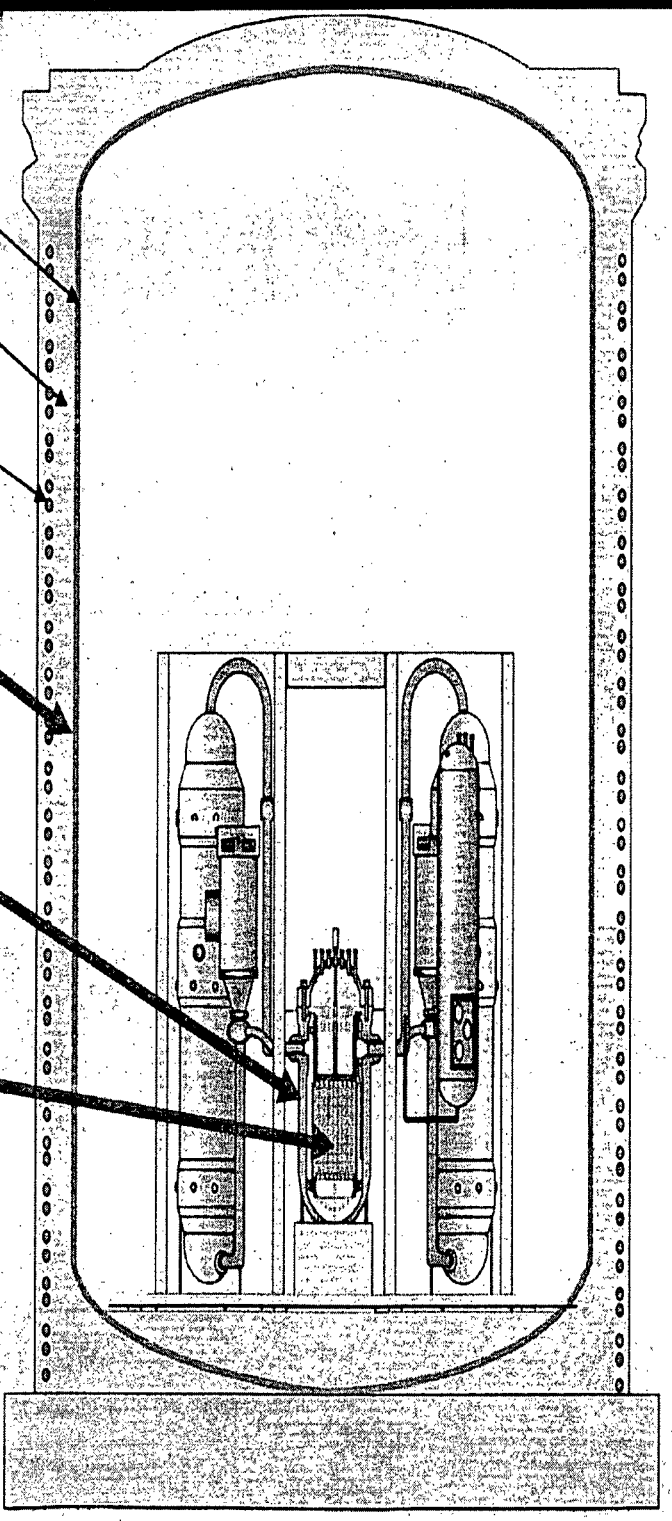
Fission Product Barriers

Simplified Schematic

DRAFT

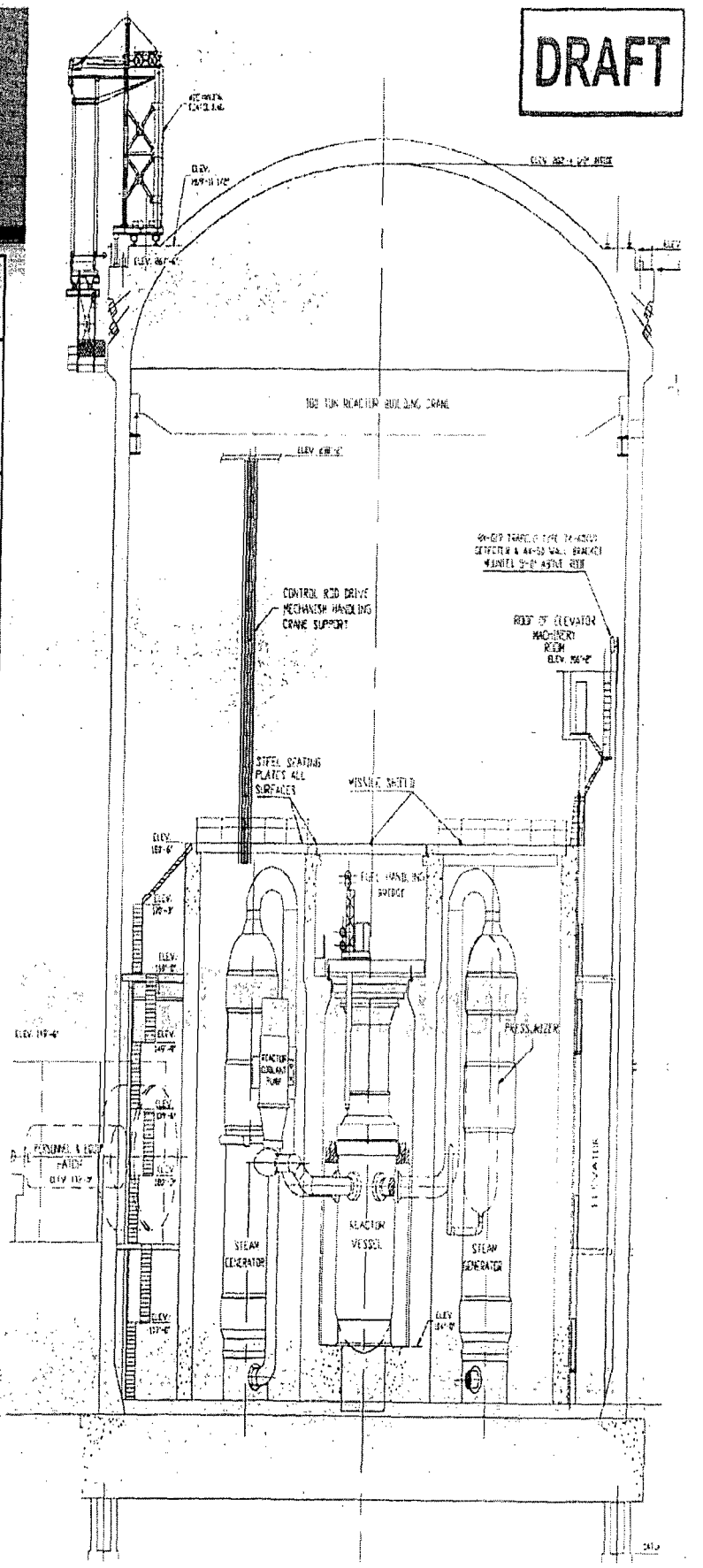


Tendon depiction is for illustrative purposes and is not an exact scale

CR3 Containment Dimensions

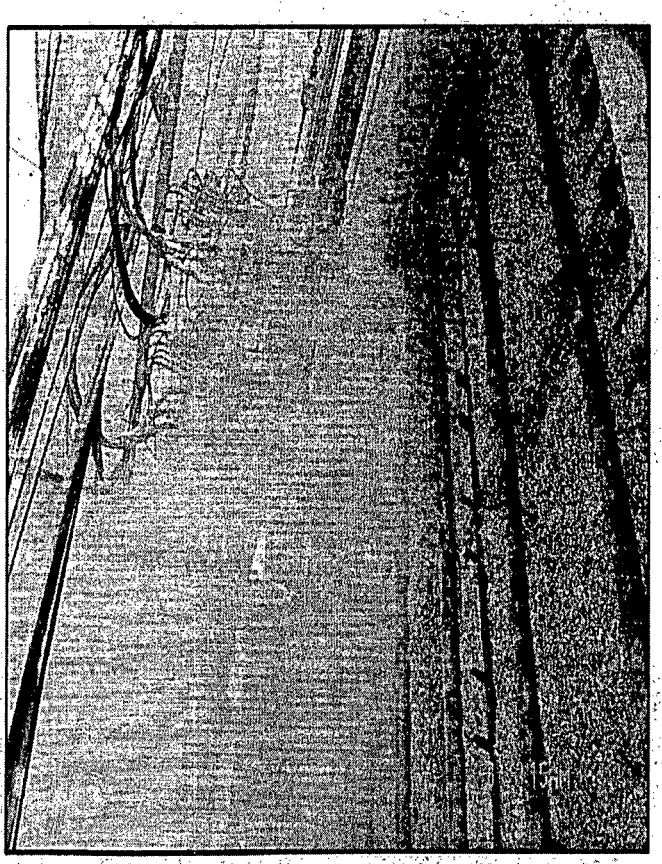
DRAFT

Dimension	Value
Containment Outside Dimension (OD)	137 ft 0.75 in
Dome Thickness	3 ft
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



DRAFT

SGR Opening Sequence & Identification of Delamination



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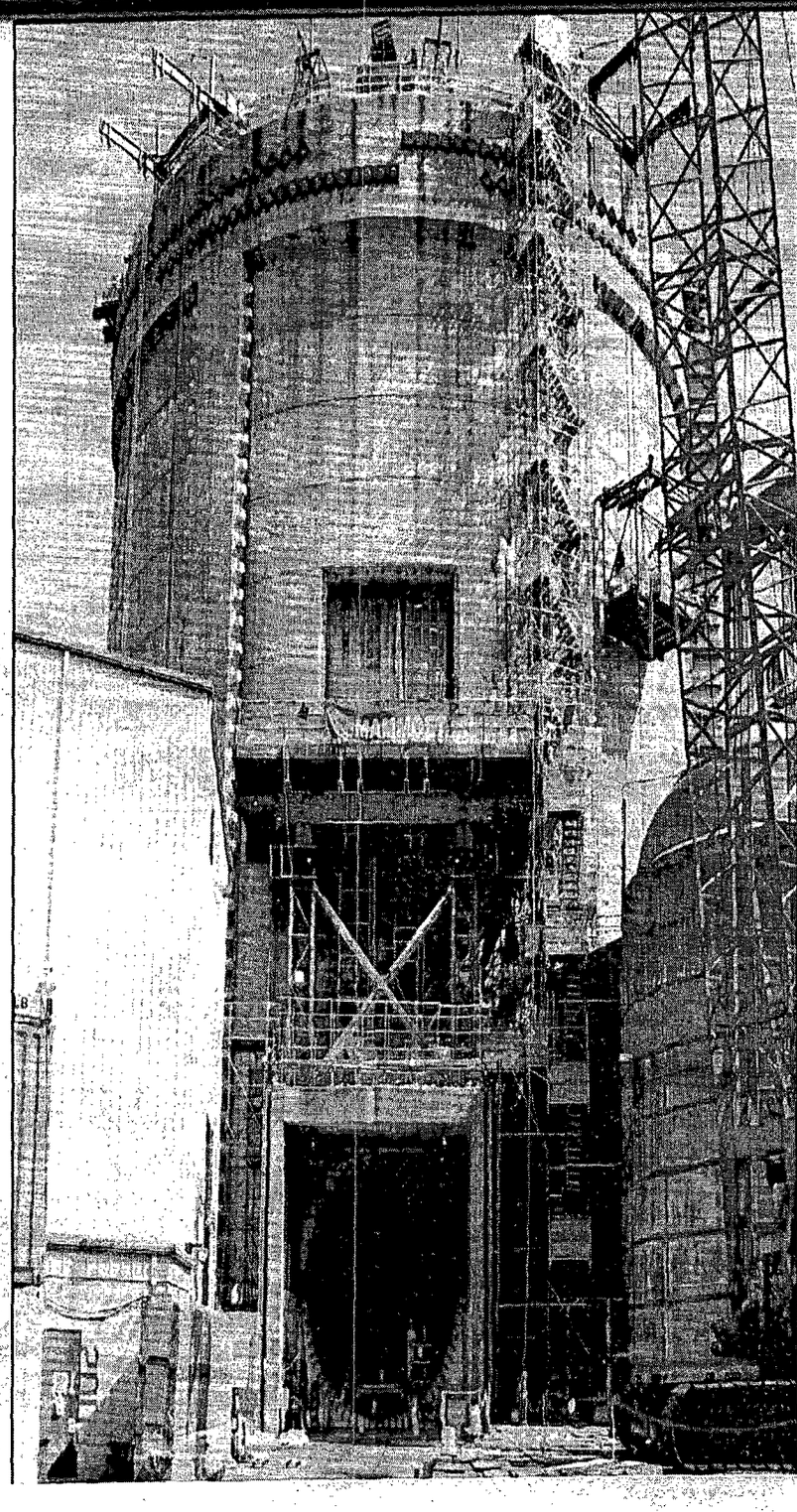
Steam Generator Replacement (SGR) Opening
(between Buttresses 3 and 4)

DRAFT



SGR Opening Dimensions

@ Liner
23' 6" x 24' 9"

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

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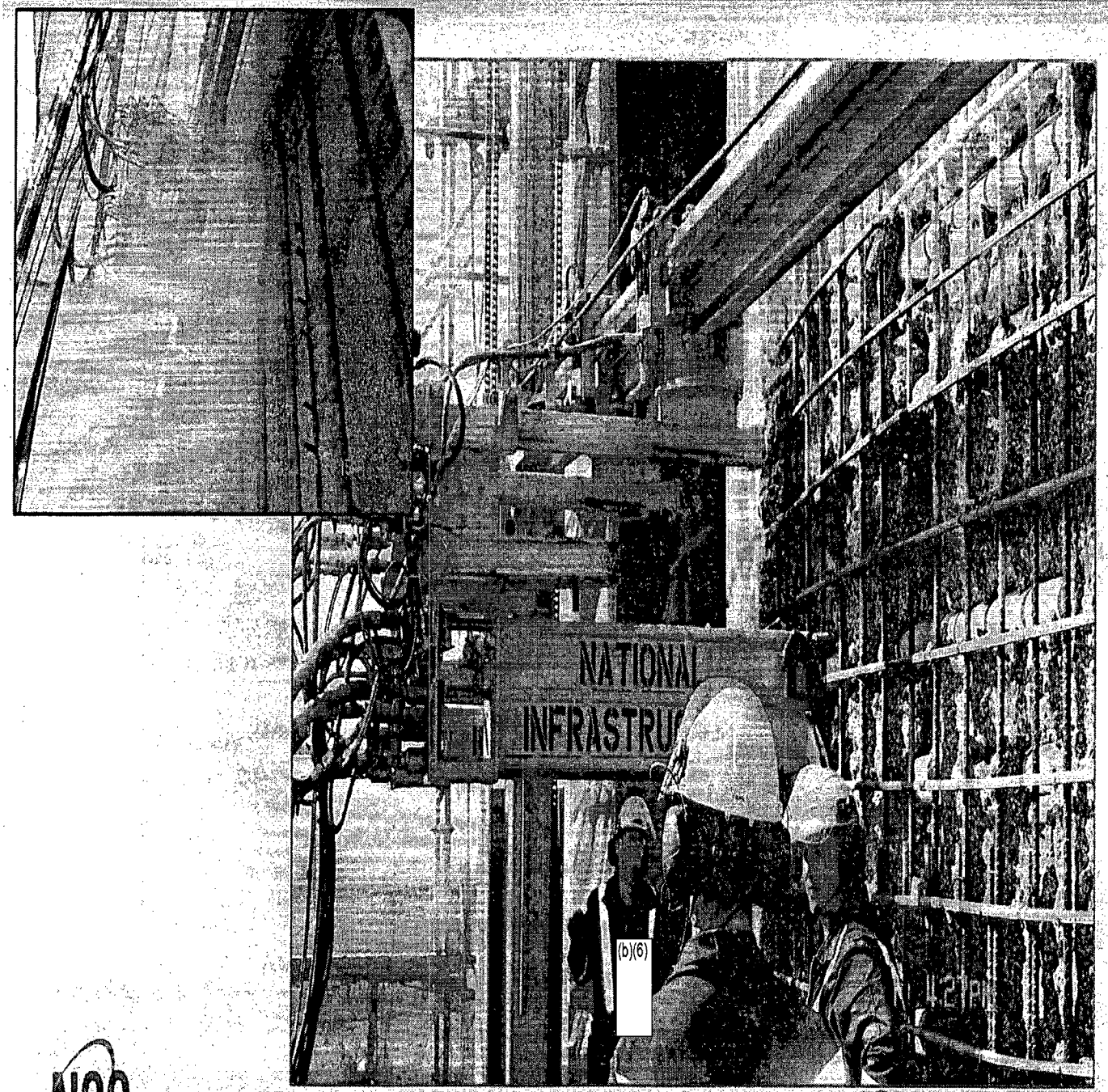
Concrete Removal



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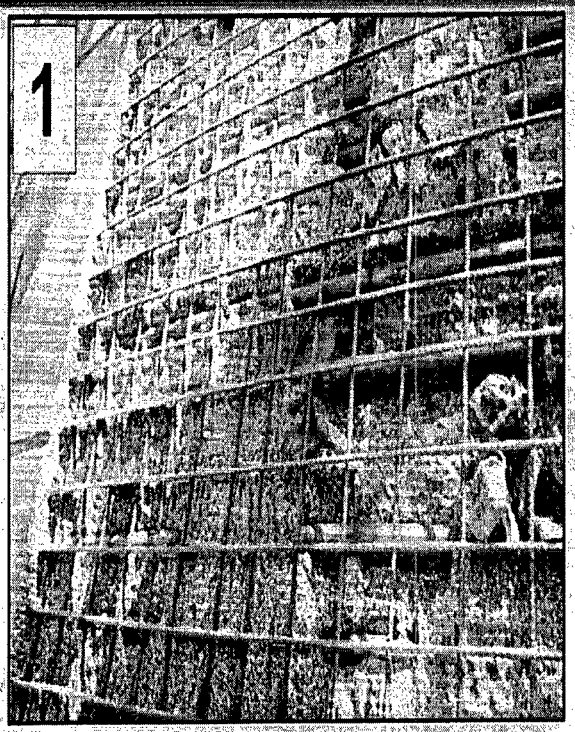
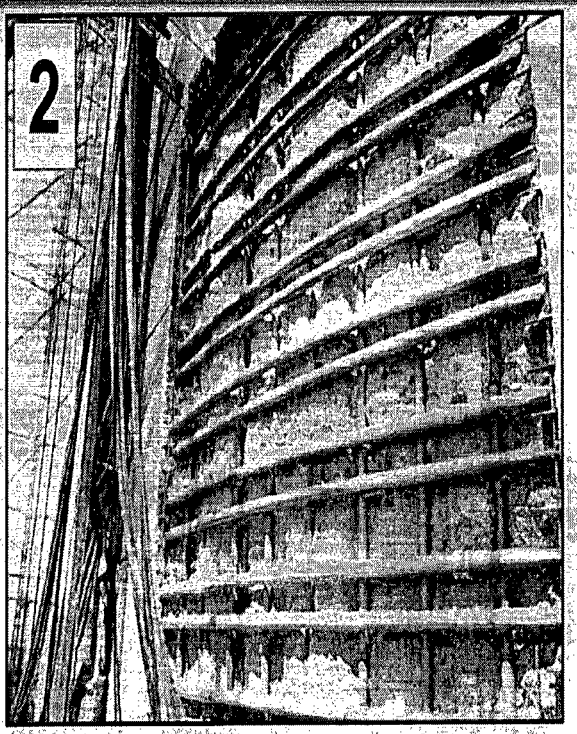
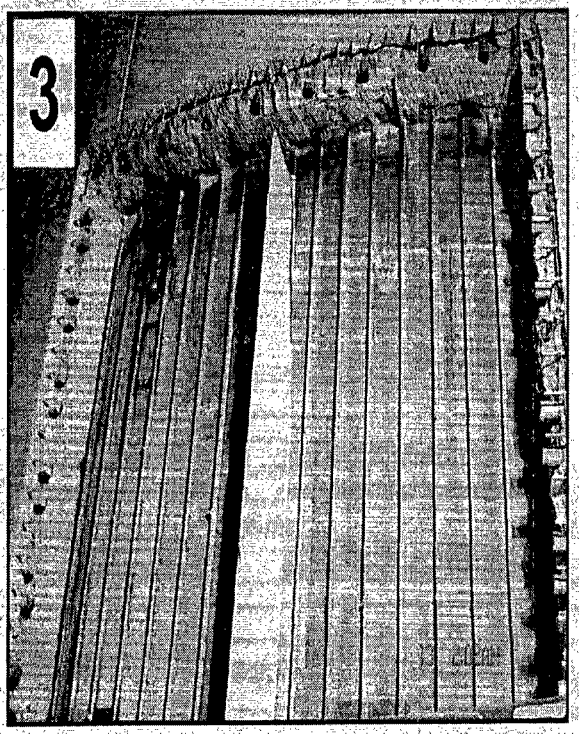
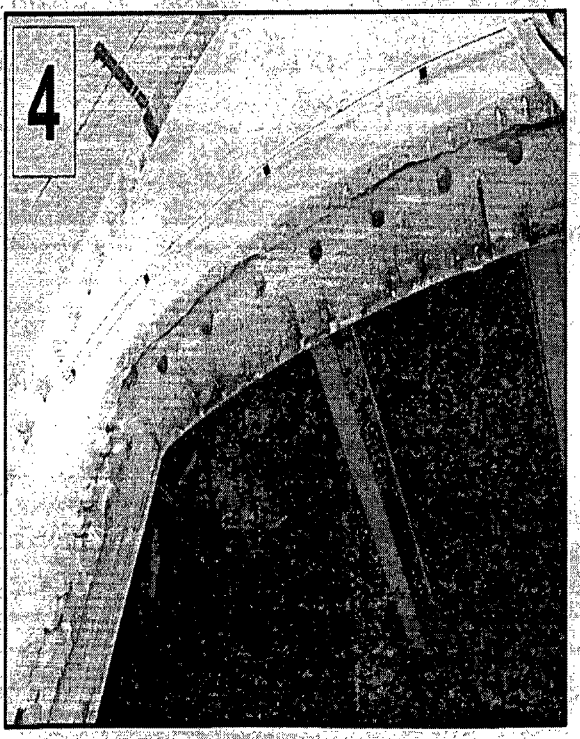
Concrete & Liner Removal Sequence



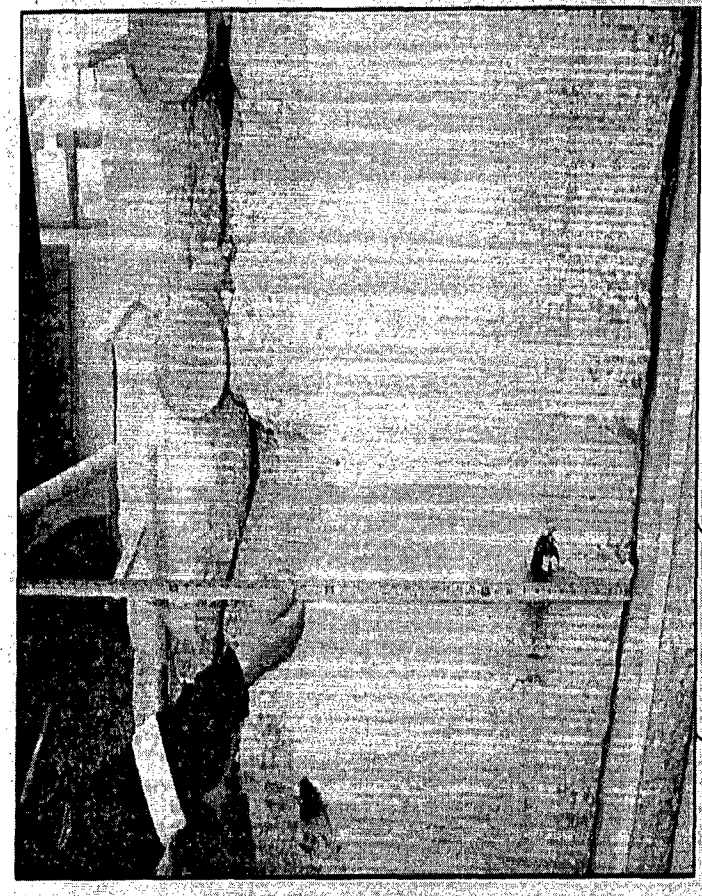


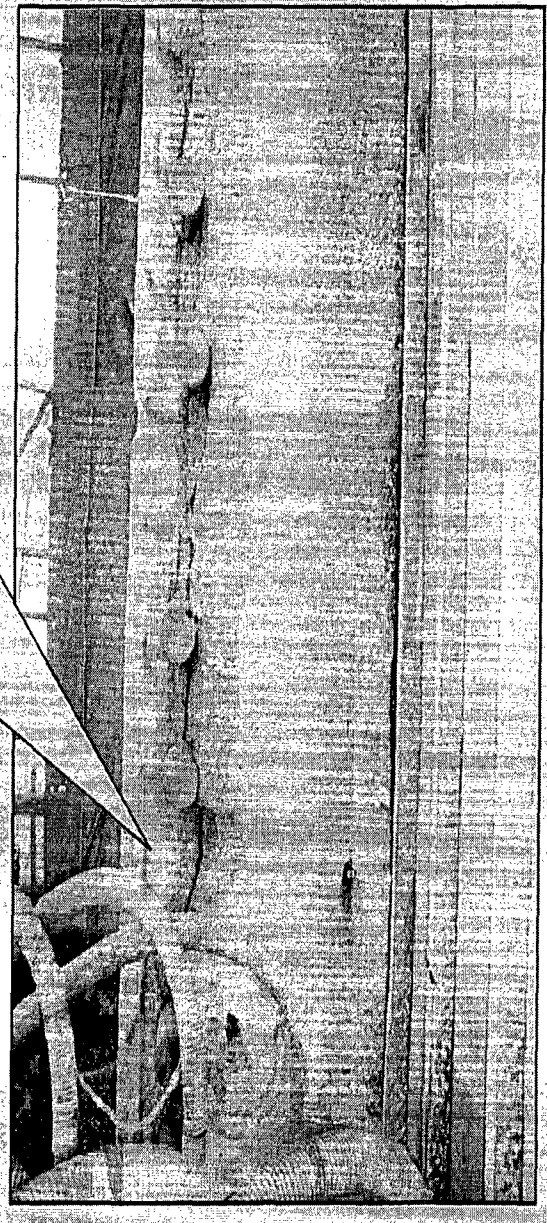




DRAFT

Delamination Close-up





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Progress Energy

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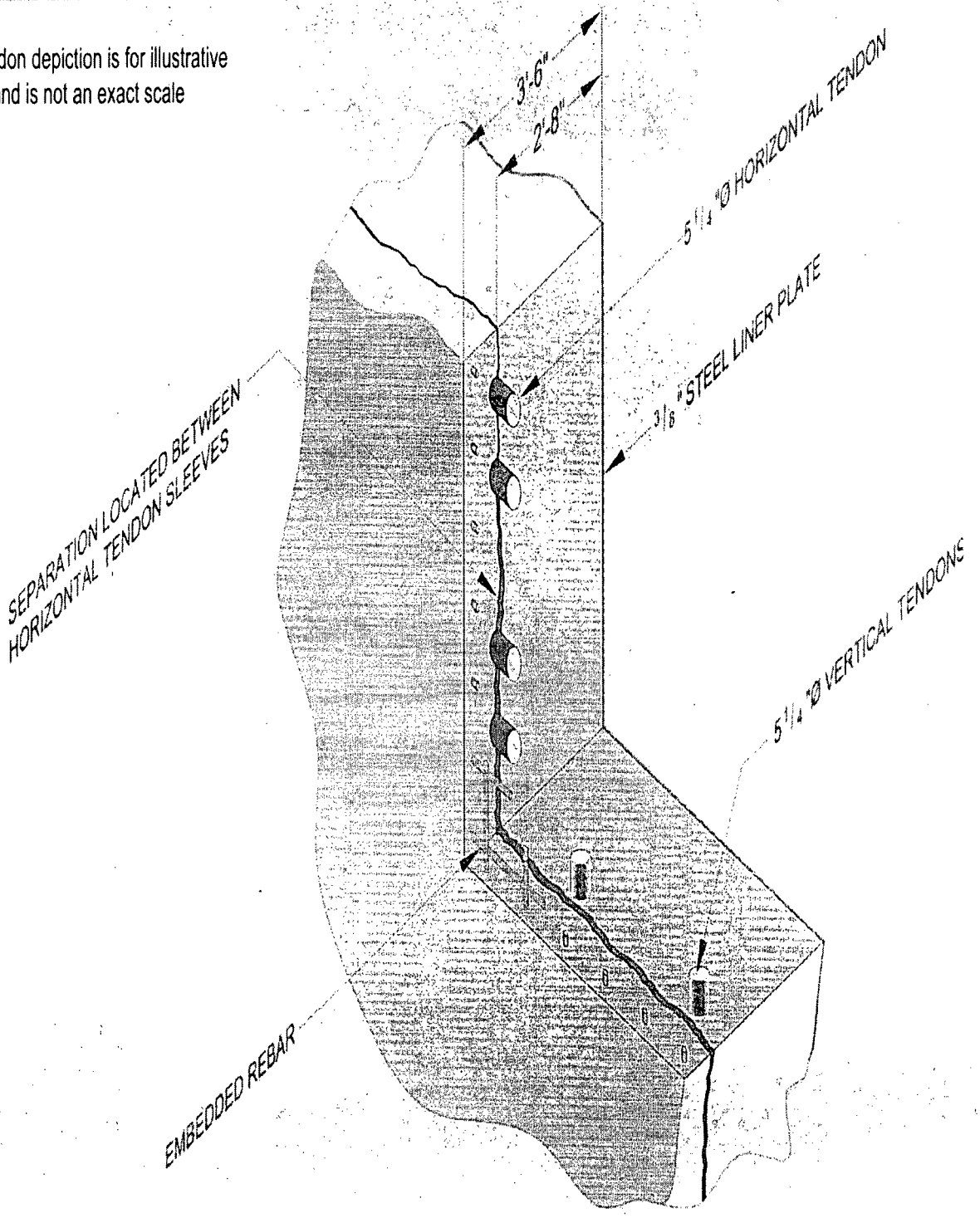
Location of the Delamination

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



DRAFT

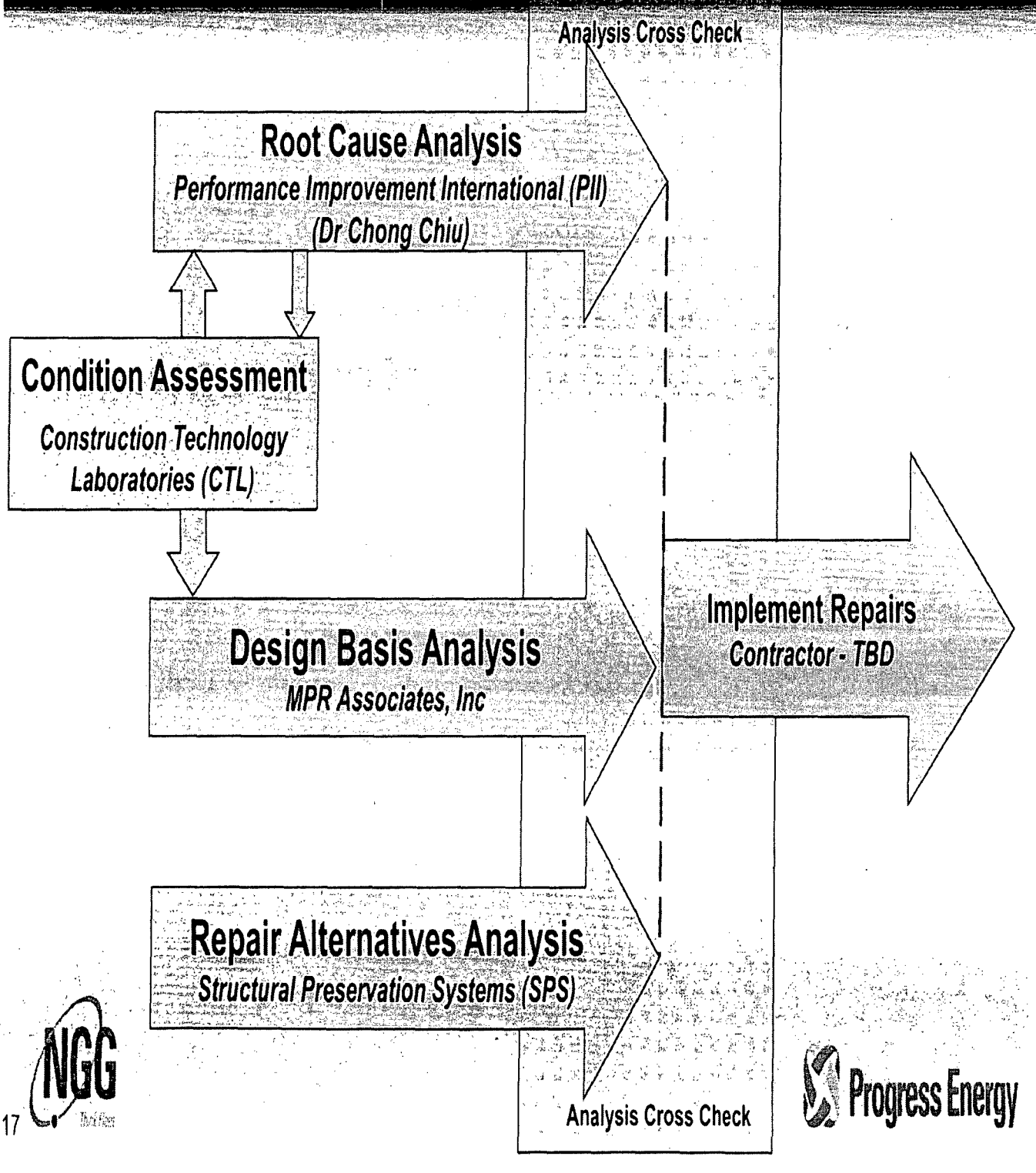
INVESTIGATION APPROACH

NGG Third Fleet

Progress Energy

Work Flow Summary

DRAFT



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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 VIS, Nuclear Inspection & Consulting, Inc; Precision Surveillance; Gulf West Surveying Inc; AREVA*
- **Root Cause Analysis**
  - Lead - ***Performance Improvement International (PII)***
  - Owner's Support - *Worley Parsons, Bechtel*

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Progress Energy

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External Support (continued)

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

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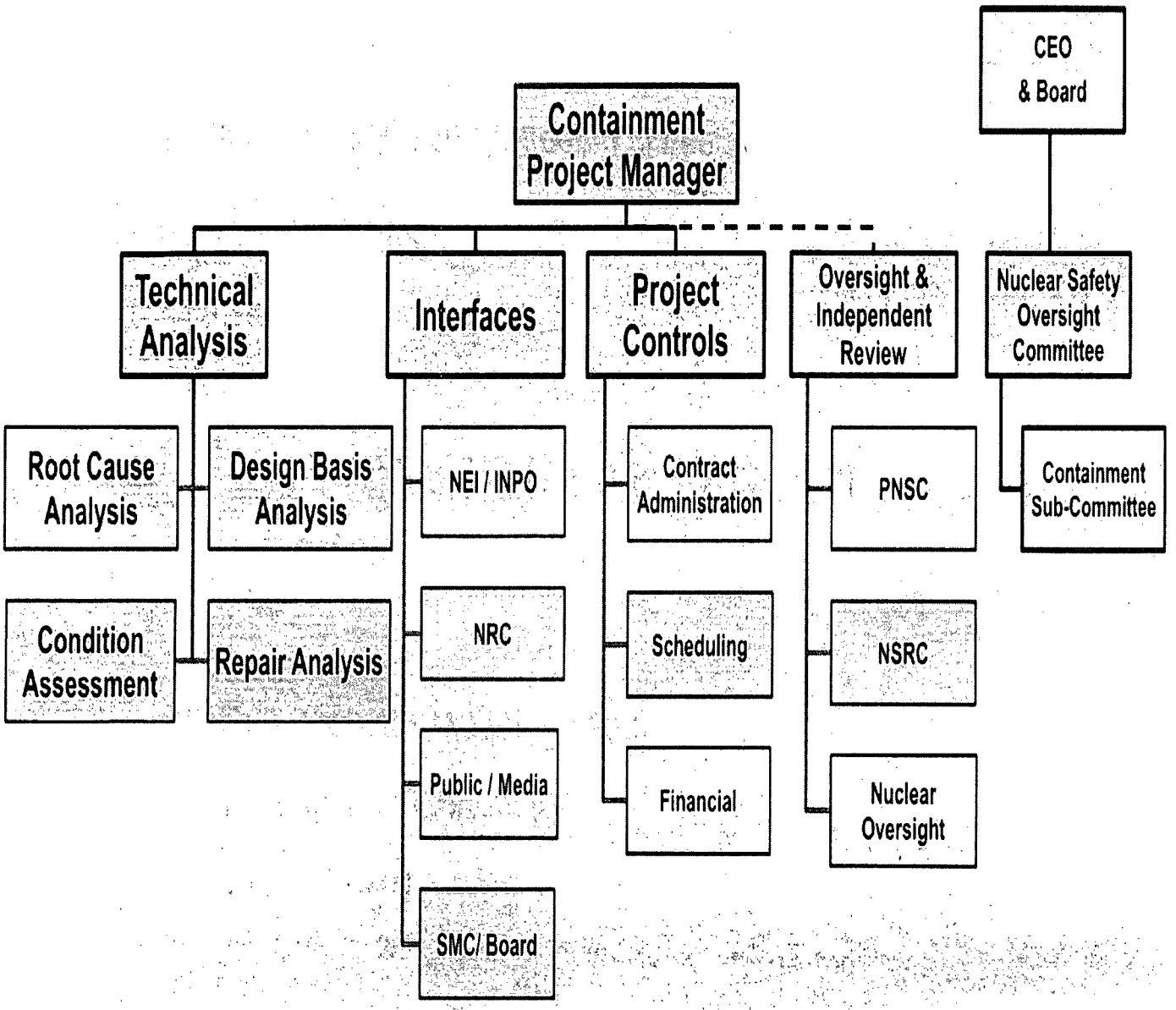
Organization – Functional View



Nuclear Safety Oversight Committee (NSOC)

DRAFT

Sub-Committee Membership

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

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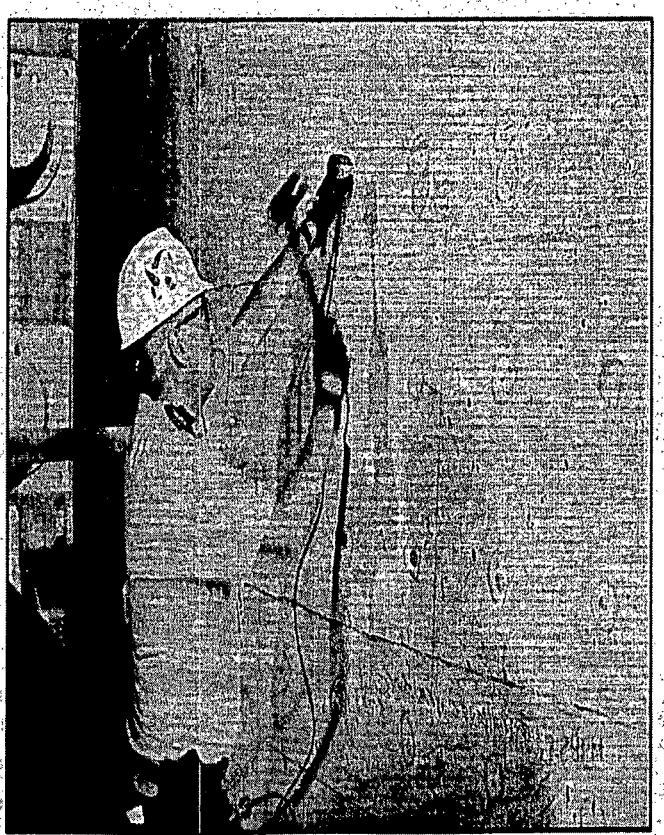
Progress Energy

DRAFT

CONDITION ASSESSMENT



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Progress Energy

Condition Assessment Activities
Completed or Planned

DRAFT

- **Determine Extent of Condition**
  - Characterize the extent of delamination within 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
  - Assessable areas accessed by surrounding buildings

NGG

Progress Energy

Condition Assessment Activities

Completed or Planned

DRAFT

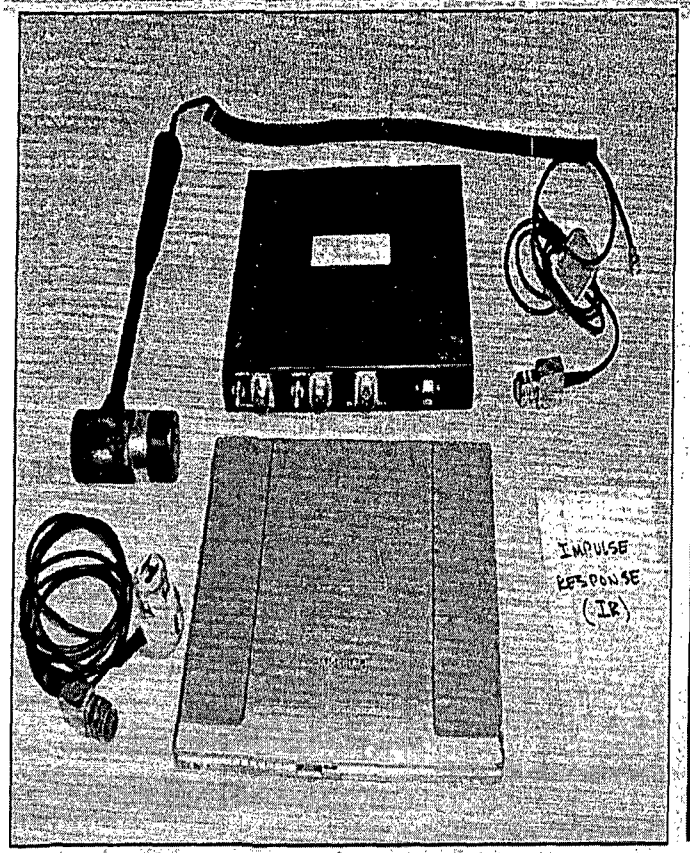
- **Concrete Cores**
  - Used to confirm IR results (over 80 cores)
  - Visual examination with boroscope to identify if delamination present
- **ASME Section XI IWL visual inspection (affected area)**
- **Containment Dome Inspections**
  - NDT IR scans in segment above the SGR opening
  - Concrete cores with boroscope examination
  - Physical survey with established benchmarks

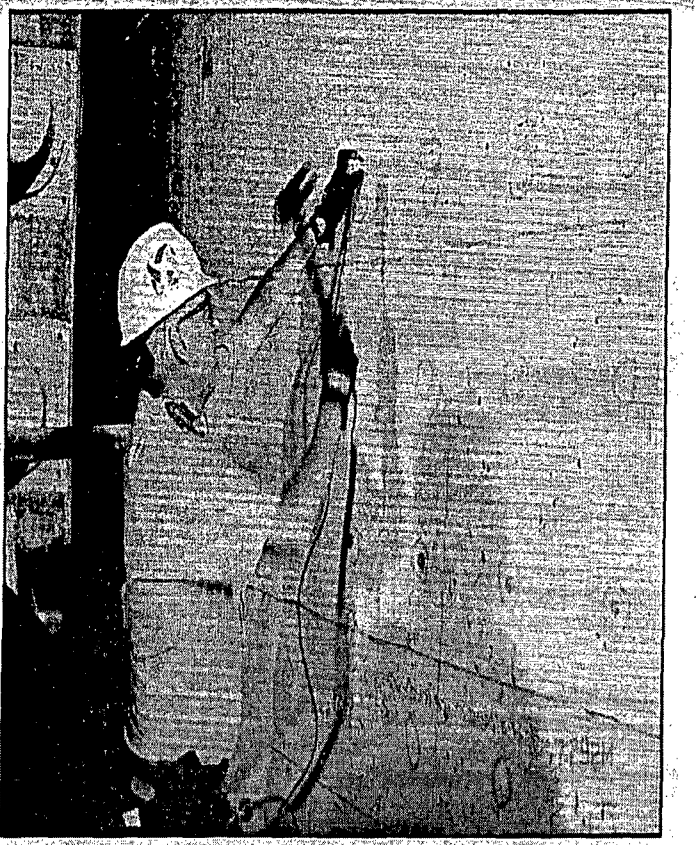
NGG

Progress Energy

Condition Assessment Techniques
Impulse Response (IR)

DRAFT





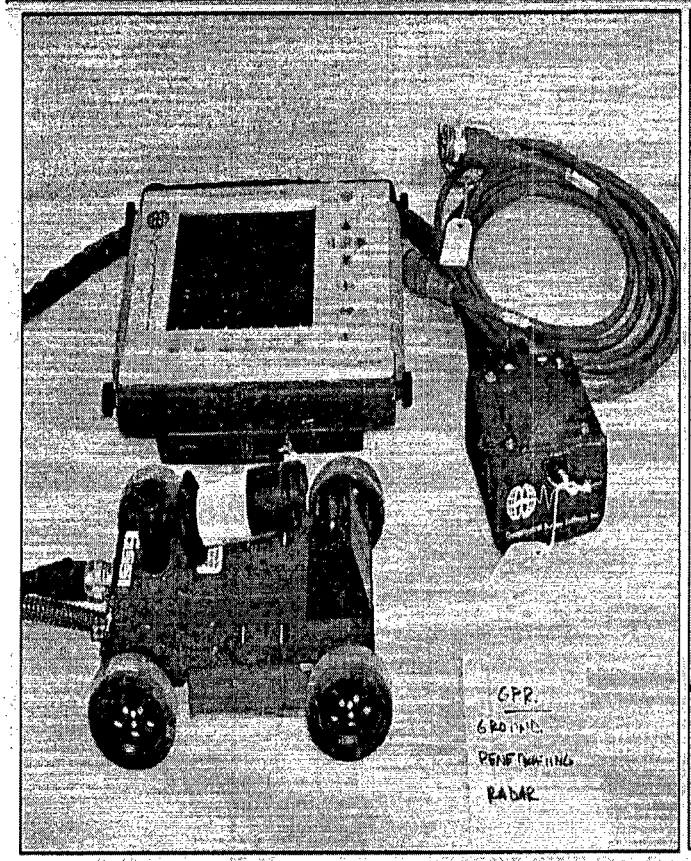
- IR Equipment
  - Primary test method used in this evaluation
- IR Performed in the Field

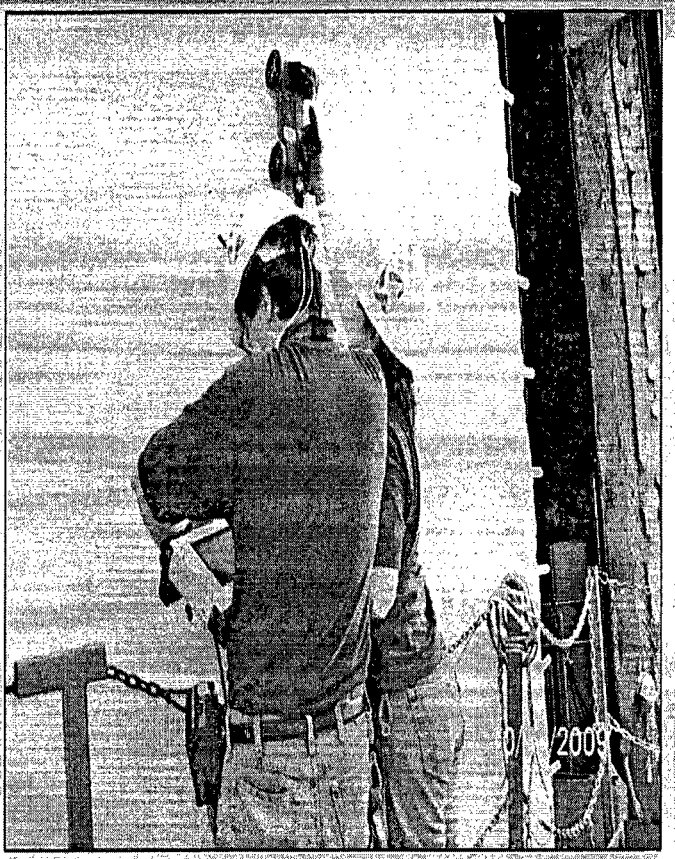
NGG

Progress Energy

Condition Assessment Techniques
Ground Penetrating Radar (GPR)

DRAFT





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

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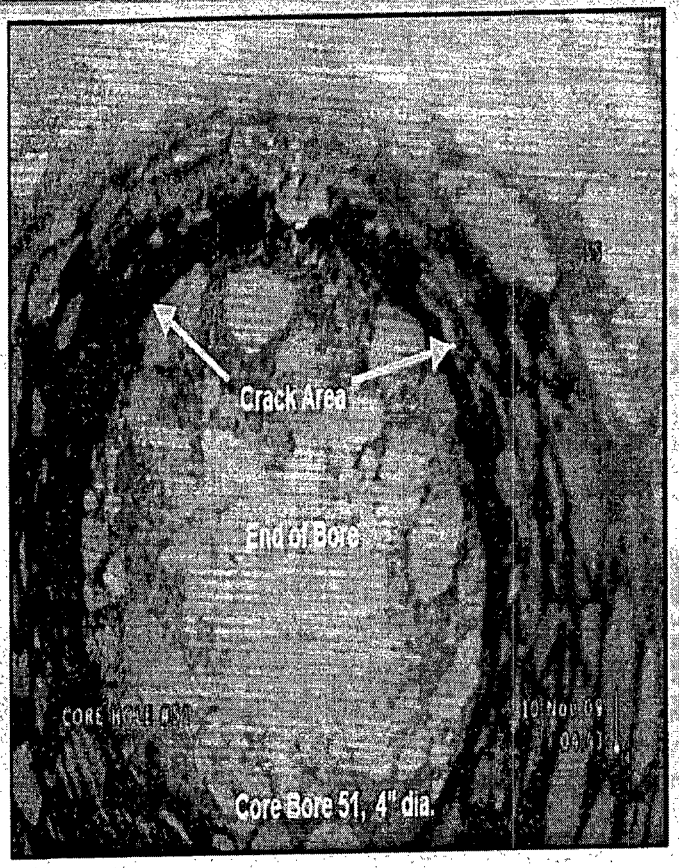
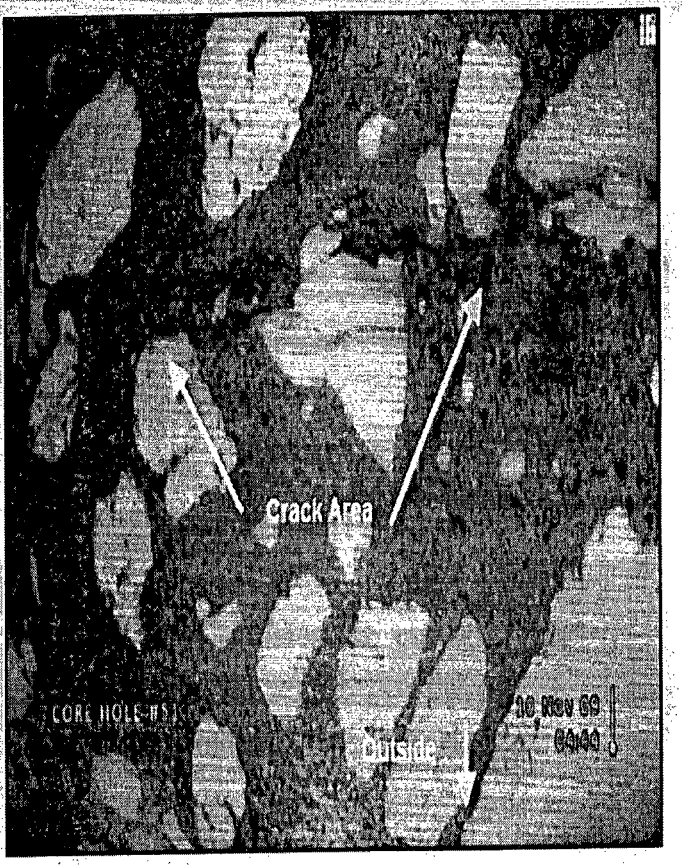
Progress Energy

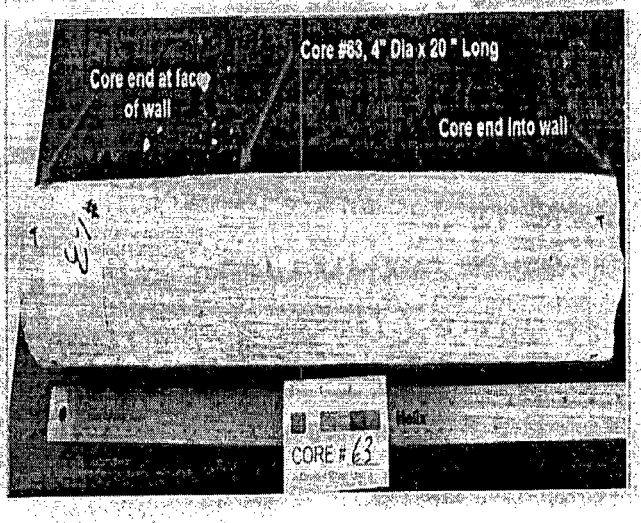
Condition Assessment Techniques
Core Bores & Boroscopic Examination

DRAFT





Examination – Inward View



Examination – Side View

Core 51, Gap 1 Depth 5-1/4"

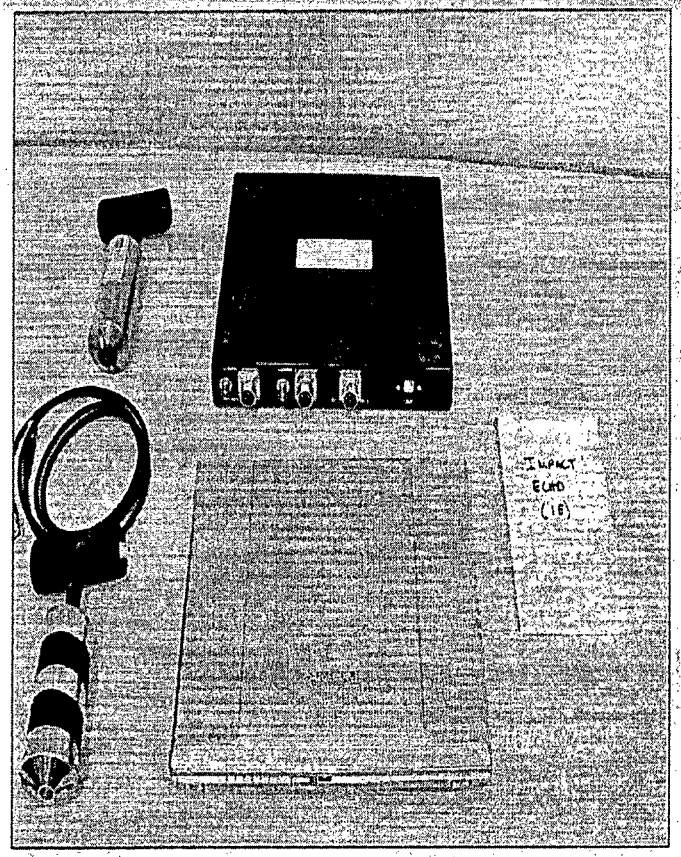
Gap 1 Width Less than 1/8"

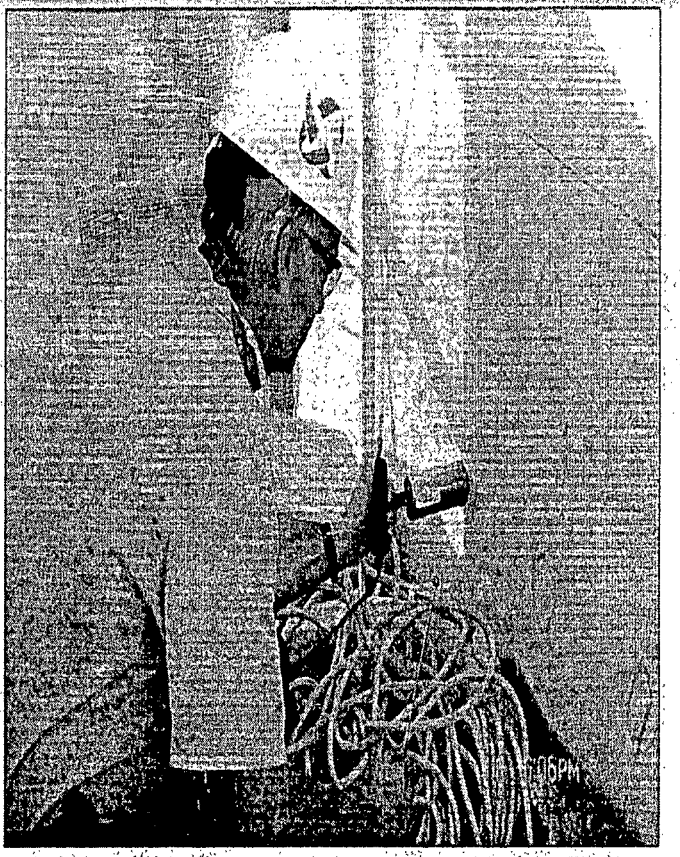
NGG

Progress Energy

Condition Assessment Techniques
Impact Echo (IE)

DRAFT





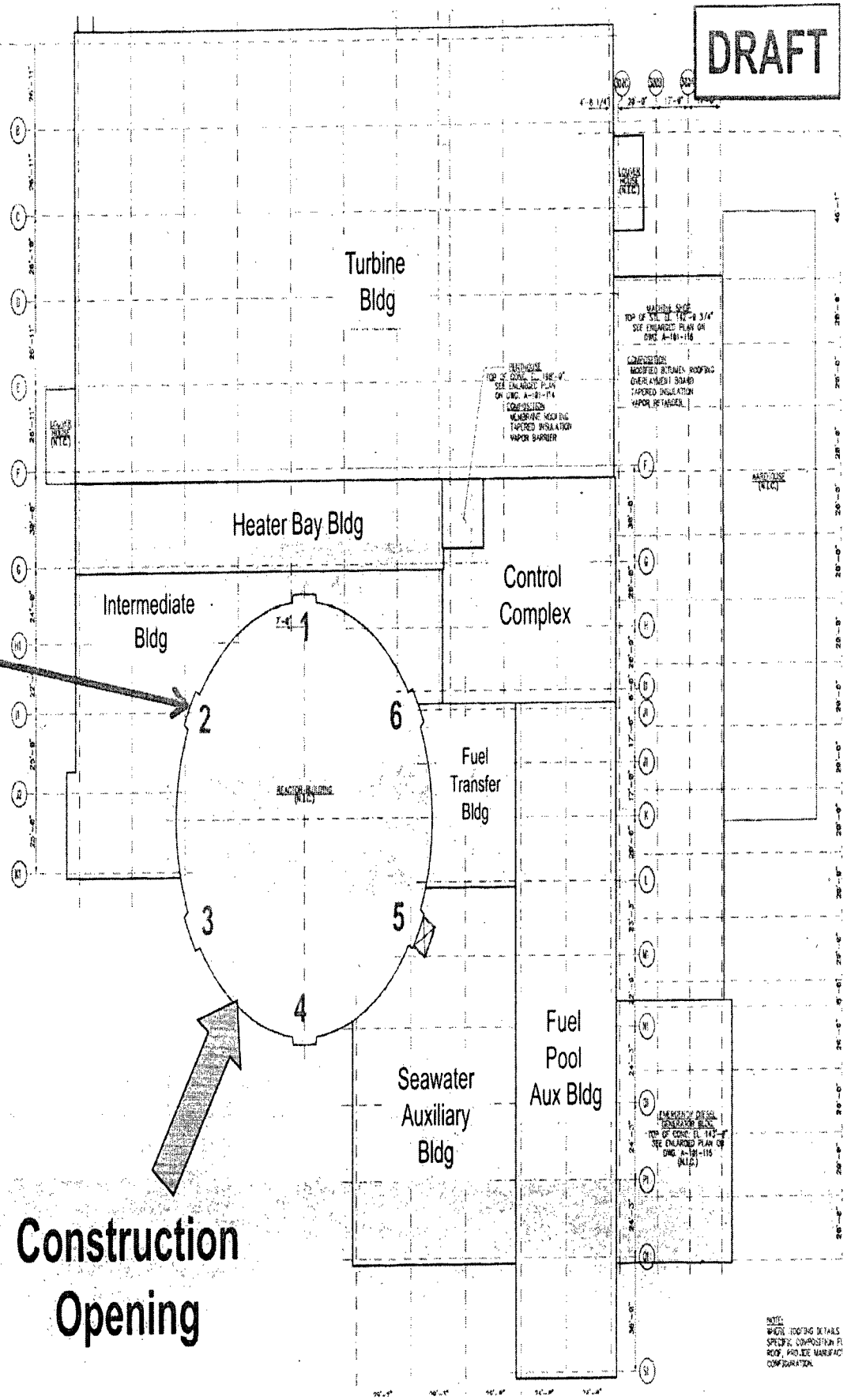
- IE Equipment
- IE Performed in the Field

NGG

Progress Energy

Plan View

DRAFT



Buttress #

(typical)

Source Drawing:

101-112 SH000

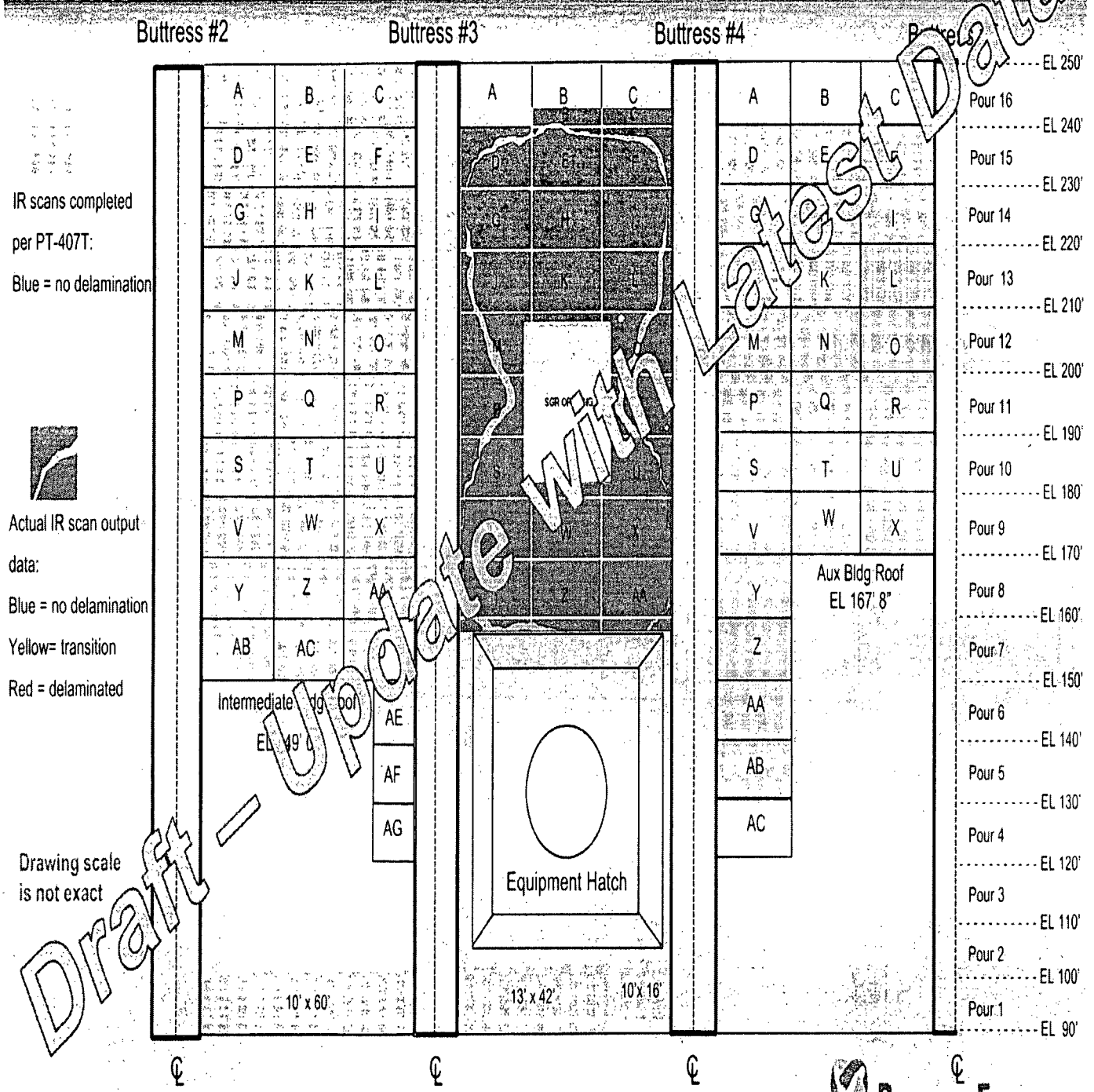
Construction Opening

NGG

Containment "Unfolded" – Buttress 2 to 5

Updated Nov 15th, Mosaic IR Overlay scale is approximate

DRAFT



Progress Energy

Containment "Unfolded" – Buttress 5 to 2

Updated Nov 15th 2009

DRAFT

Draft – Update with Latest Data

Buttress #5 | Buttress #6 | Buttress #1 | Buttress 2

IR scans completed per PT 407T:

Blue = no delamination

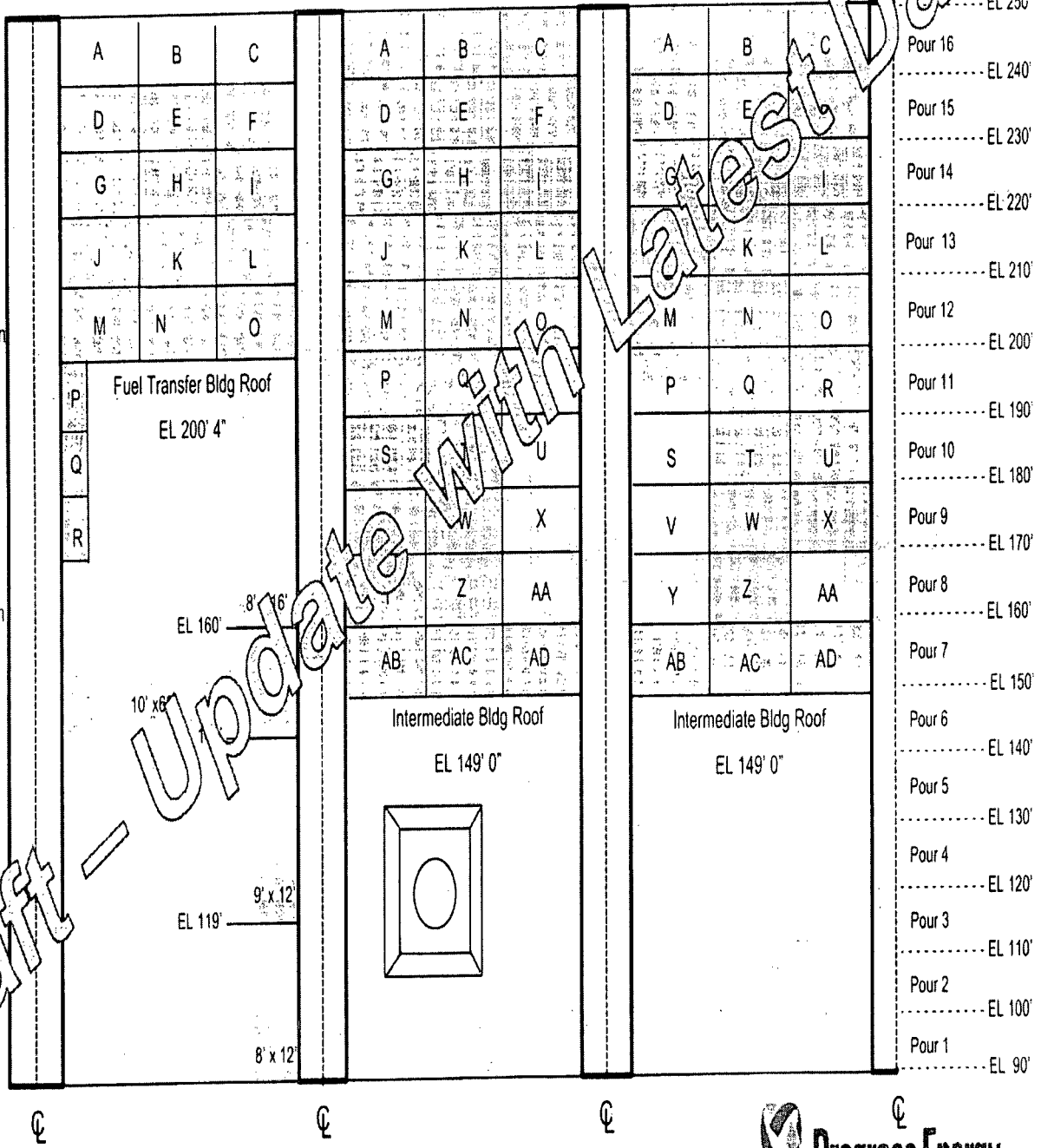
Actual IR scan output data:

Blue = no delamination

Yellow= transition

Red = delaminated

Drawing scale is not exact

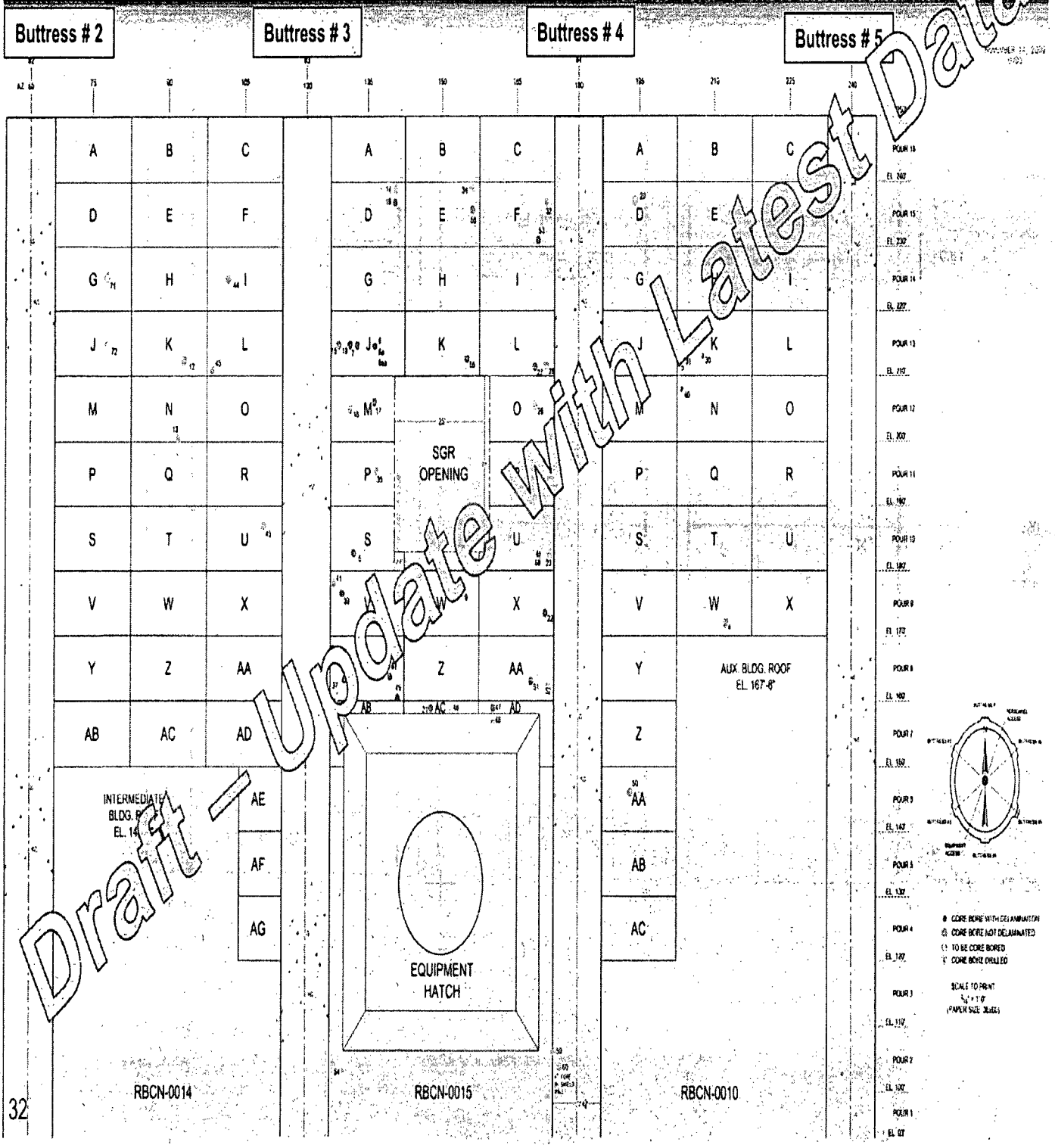


Progress Energy

Core Bores

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

DRAFT

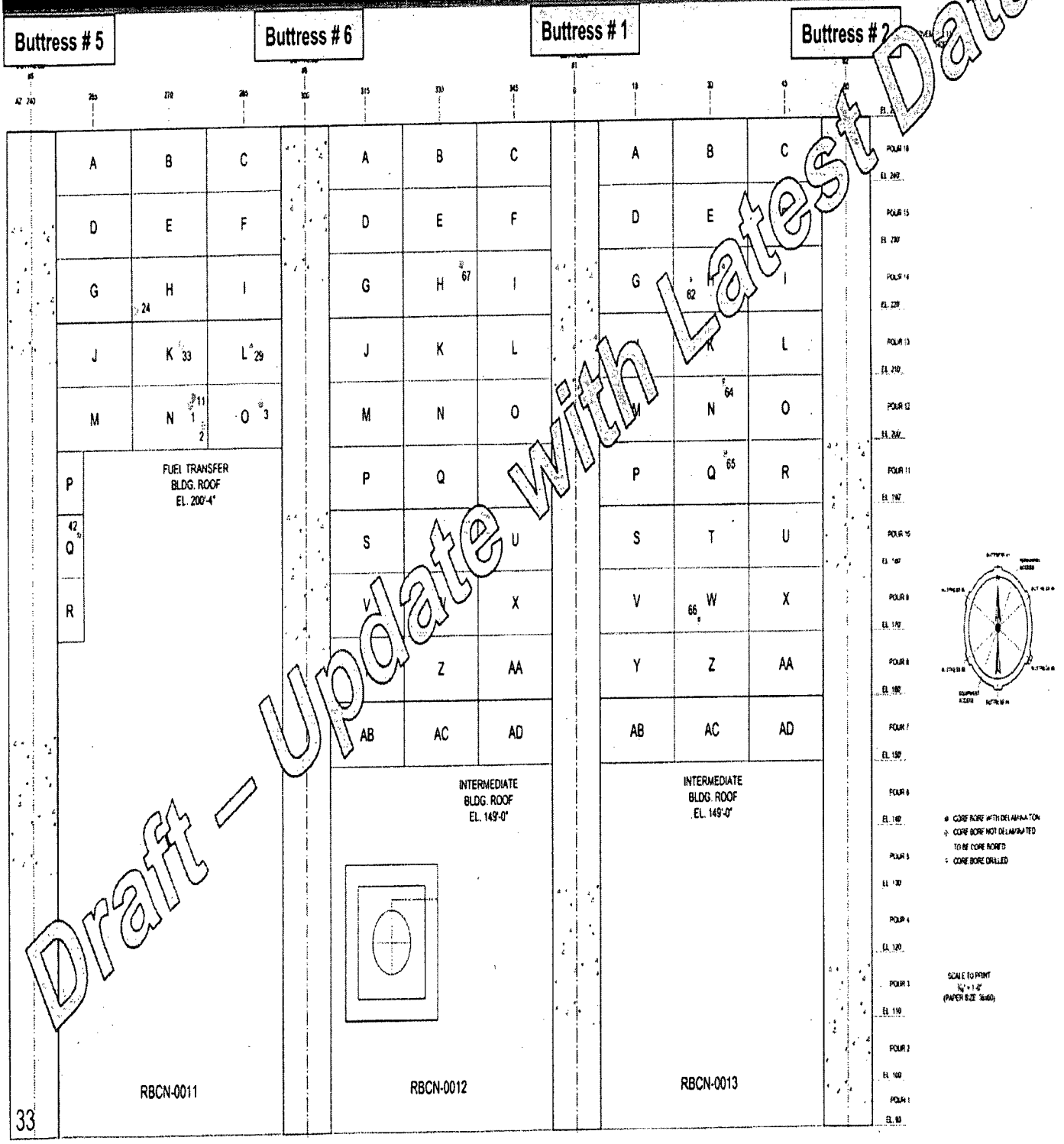


Draft – Update with Latest Data

Core Bores

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

DRAFT

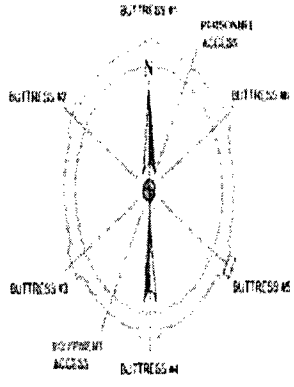


Draft – Update with Latest Data

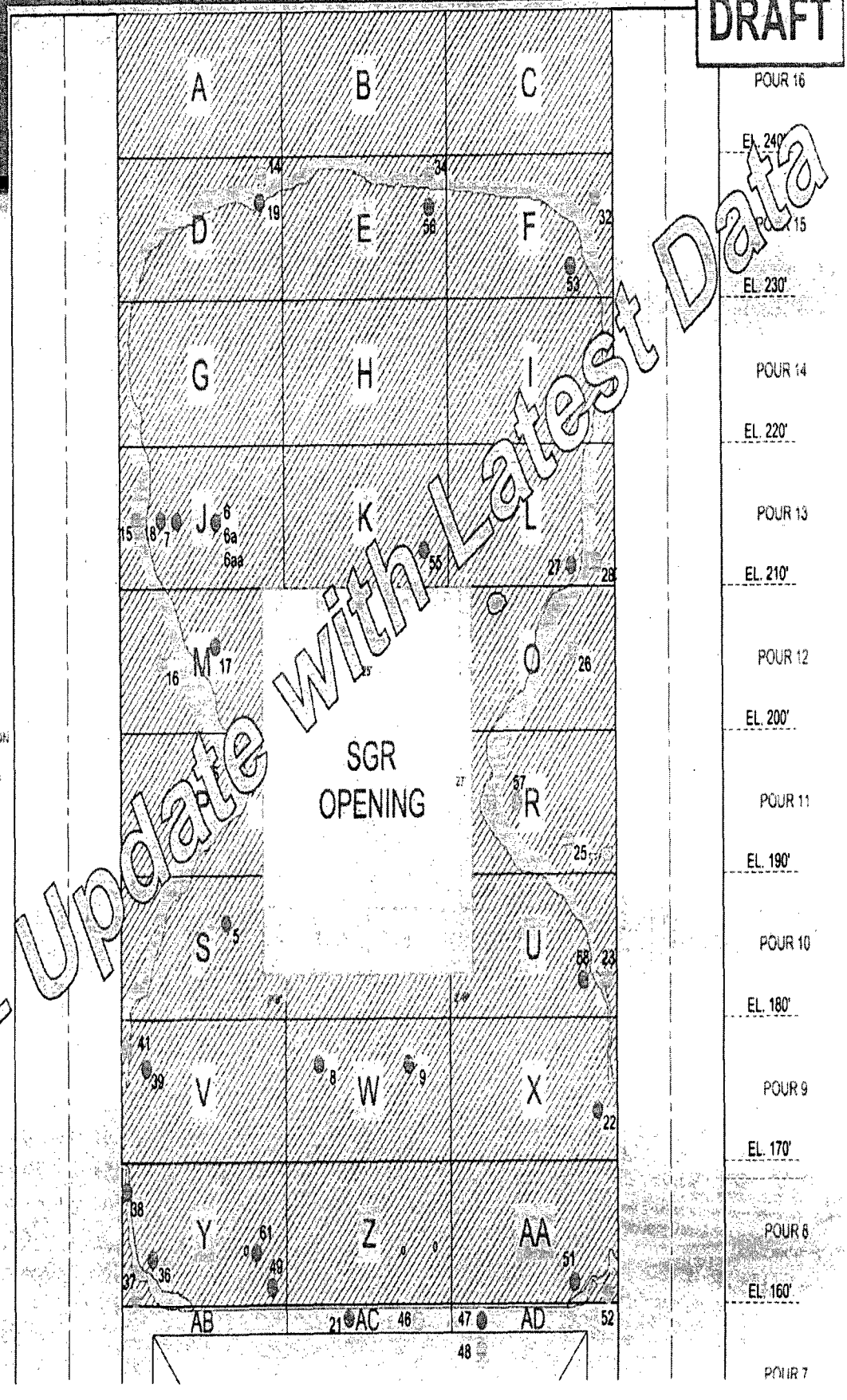
33

Core Borings

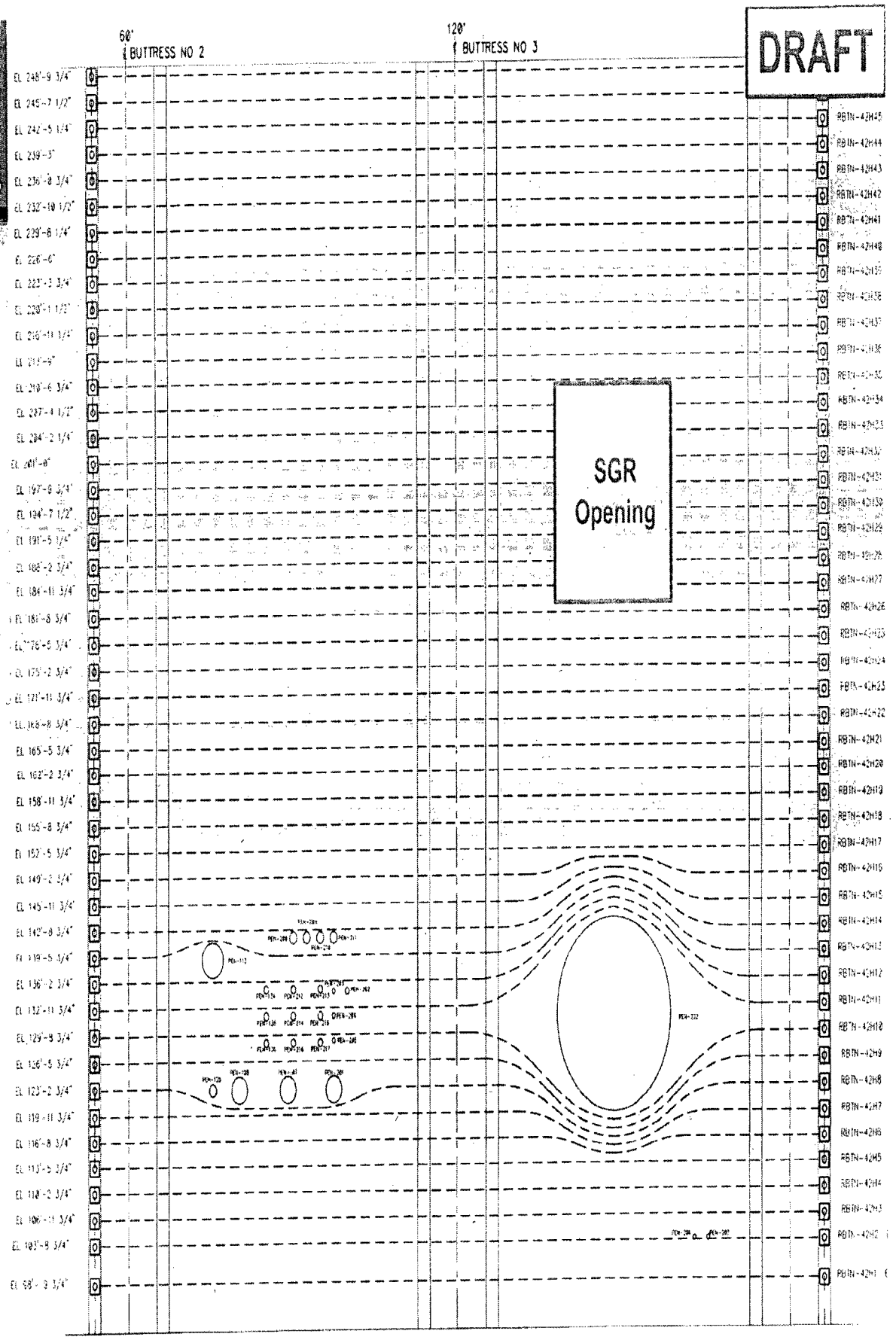
DRAFT



- CORE BORE WITH DELAMINATION
- CORE BORE NOT DELAMINATED
- TO BE CORE BORED
- CORE BORE DRILLED



Horizontal Tendons Buttress 2 - 4



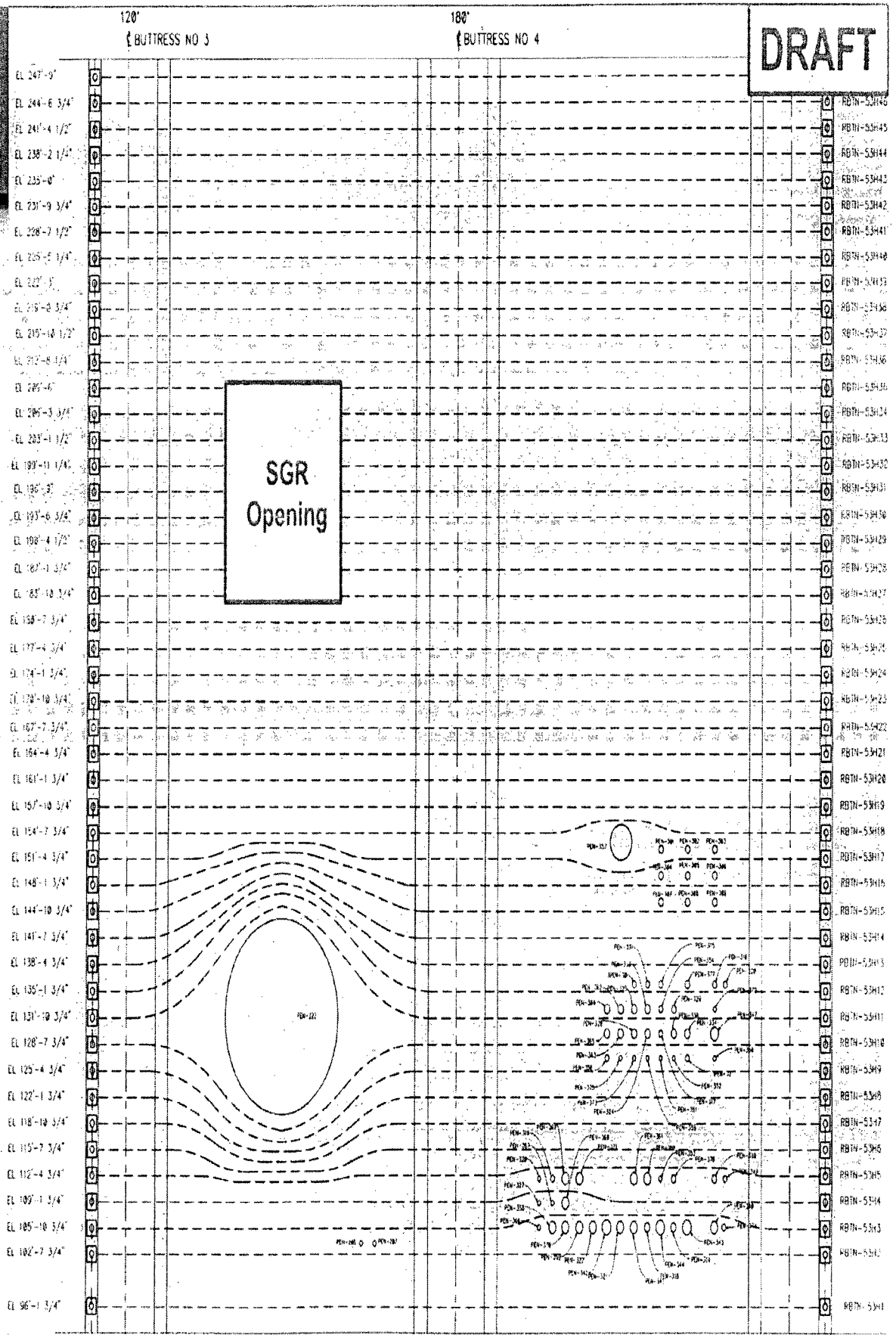
Additional tendons to be detensioned for SGR opening (pre-outage plan)

Tendons Removed

Additional tendons to be detensioned for SGR opening (pre-outage plan)

Source Drawing: 0425-006 SH001 - SH 000

Horizontal Tendons Buttress 3 - 5



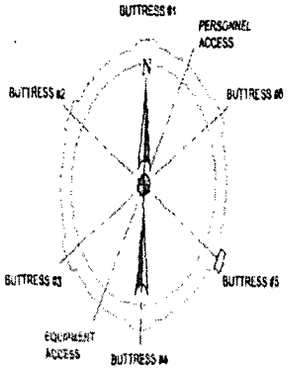
Additional tendons to be detensioned for SGR opening (pre-outage plan)

Tendons Removed

Additional tendons to be detensioned for SGR opening (pre-outage plan)

Source Drawing: 0425-007 SH001 - SH 000

Vertical Tendons)



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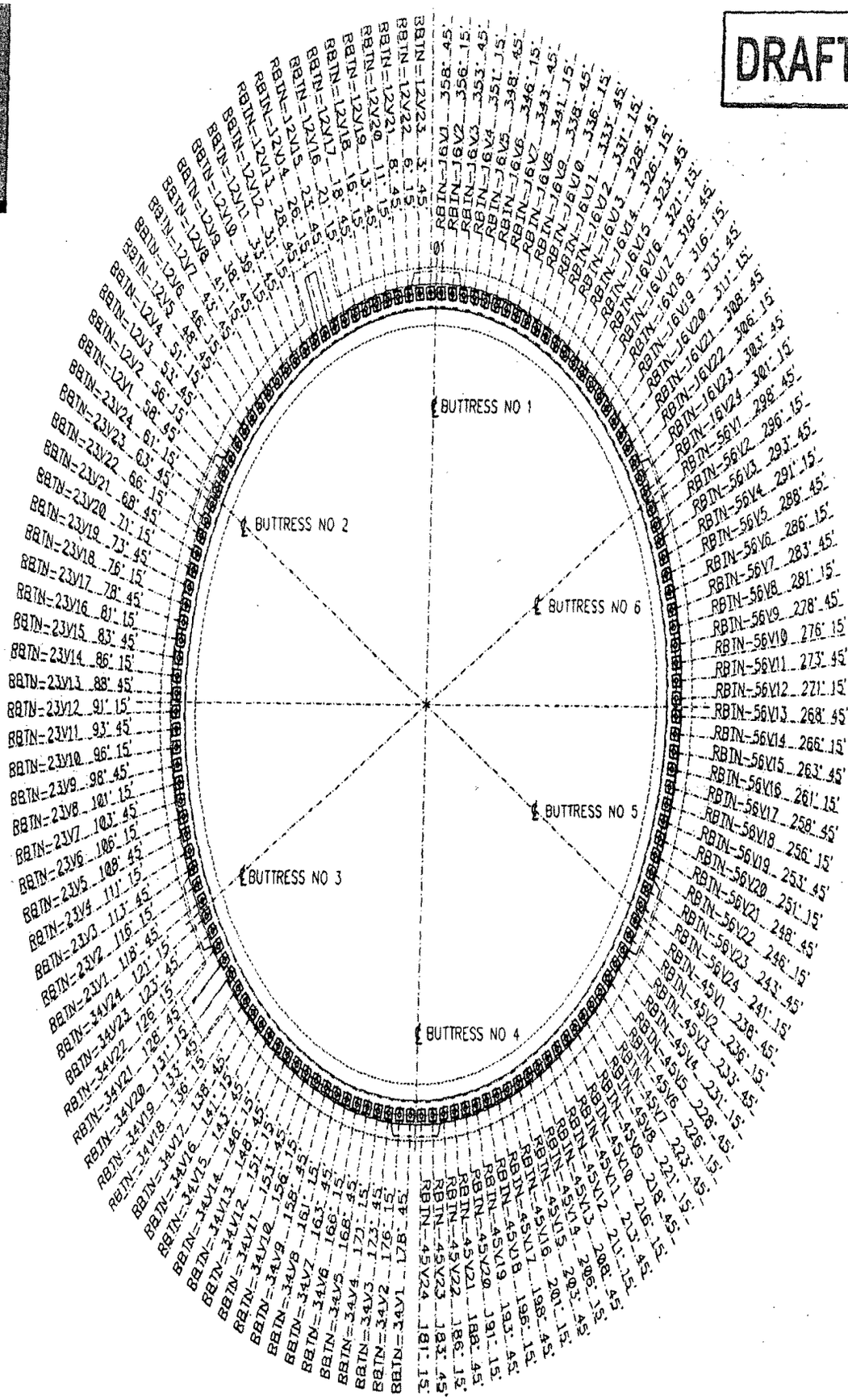
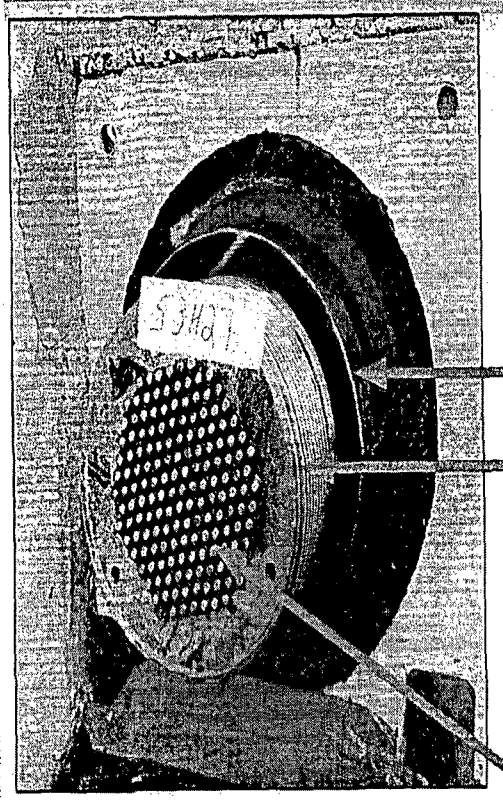
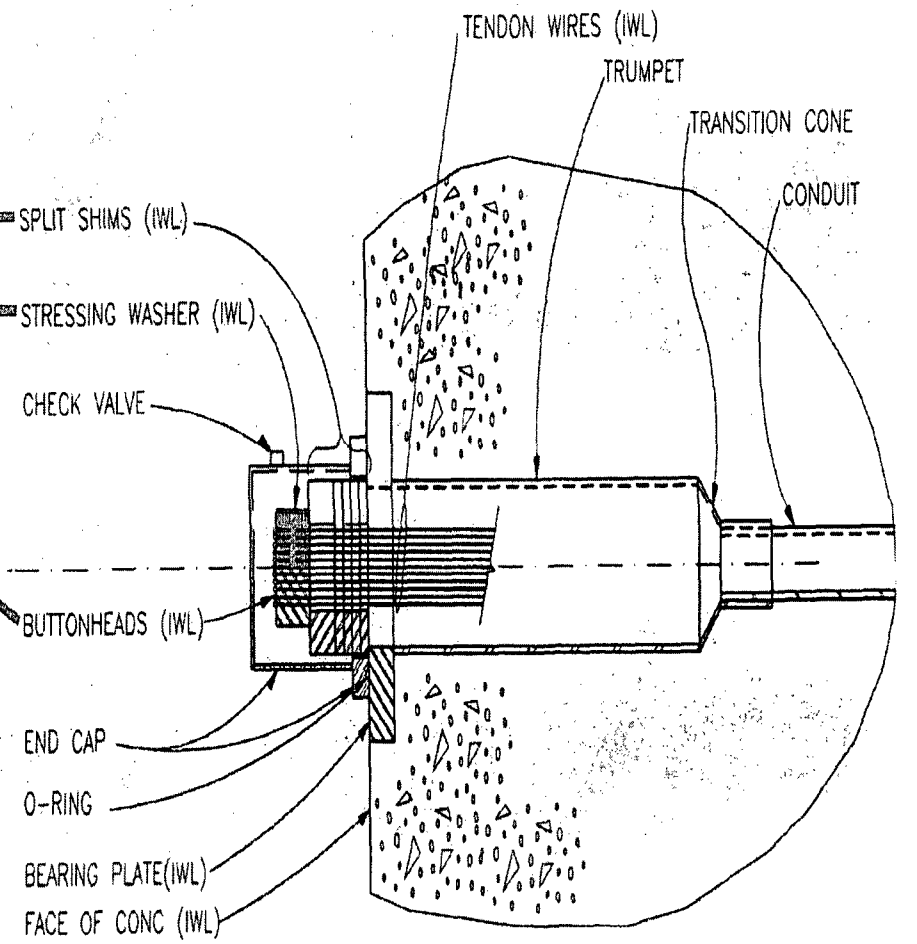


CR3 Typical Tendon Schematic and Photo (for horizontal tendon # 53H27)

DRAFT





SECTION

Source Drawing:
425-020-SH-001-SH000

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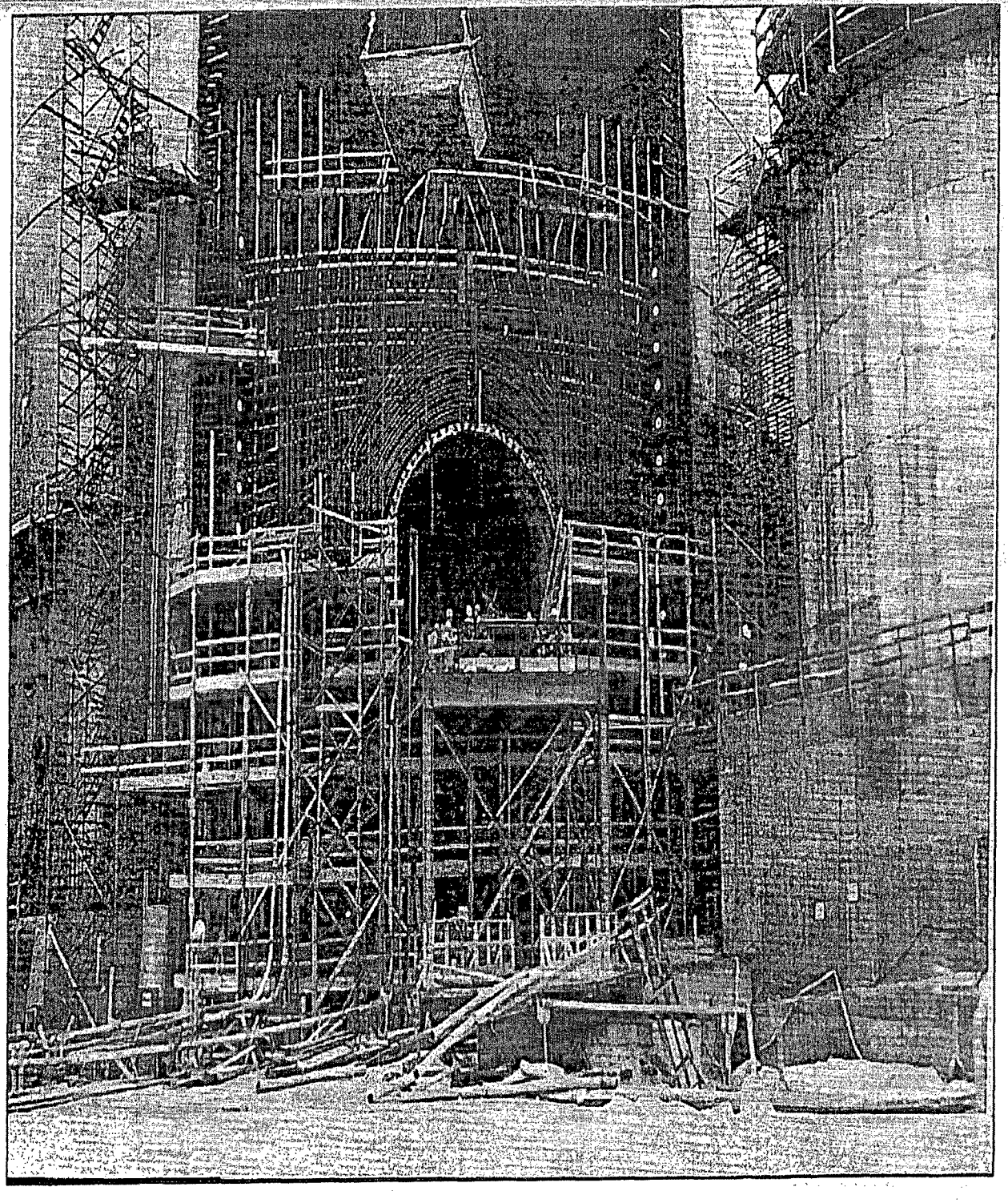
Progress Energy

Equipment Hatch Opening Reinforcement Photo - 30 Nov 1972

DRAFT



Tendon Pattern

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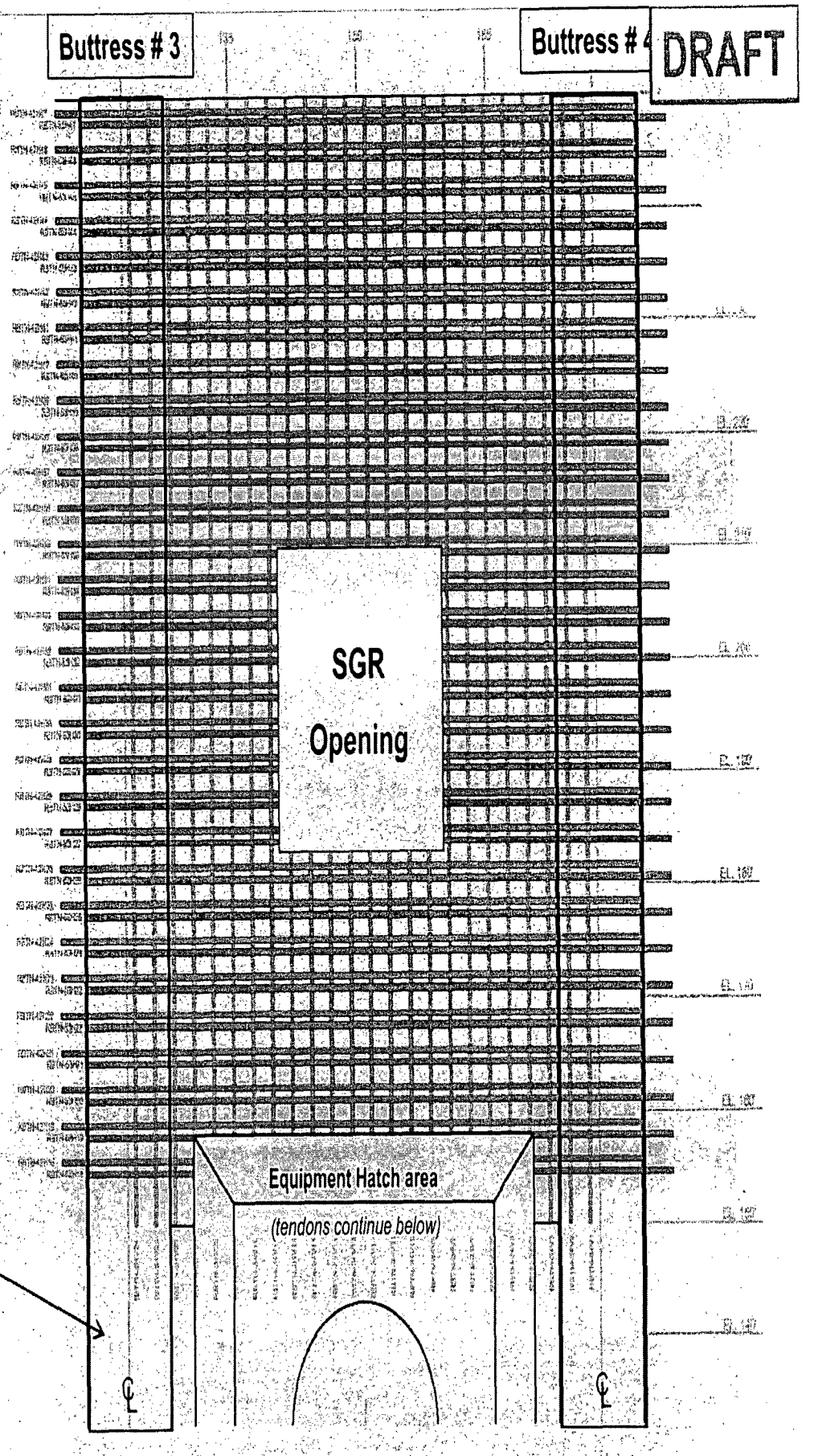

Tendon Pattern at time of cutting SGR Opening

Energized Tendon

Removed Tendon

Tendon Pattern

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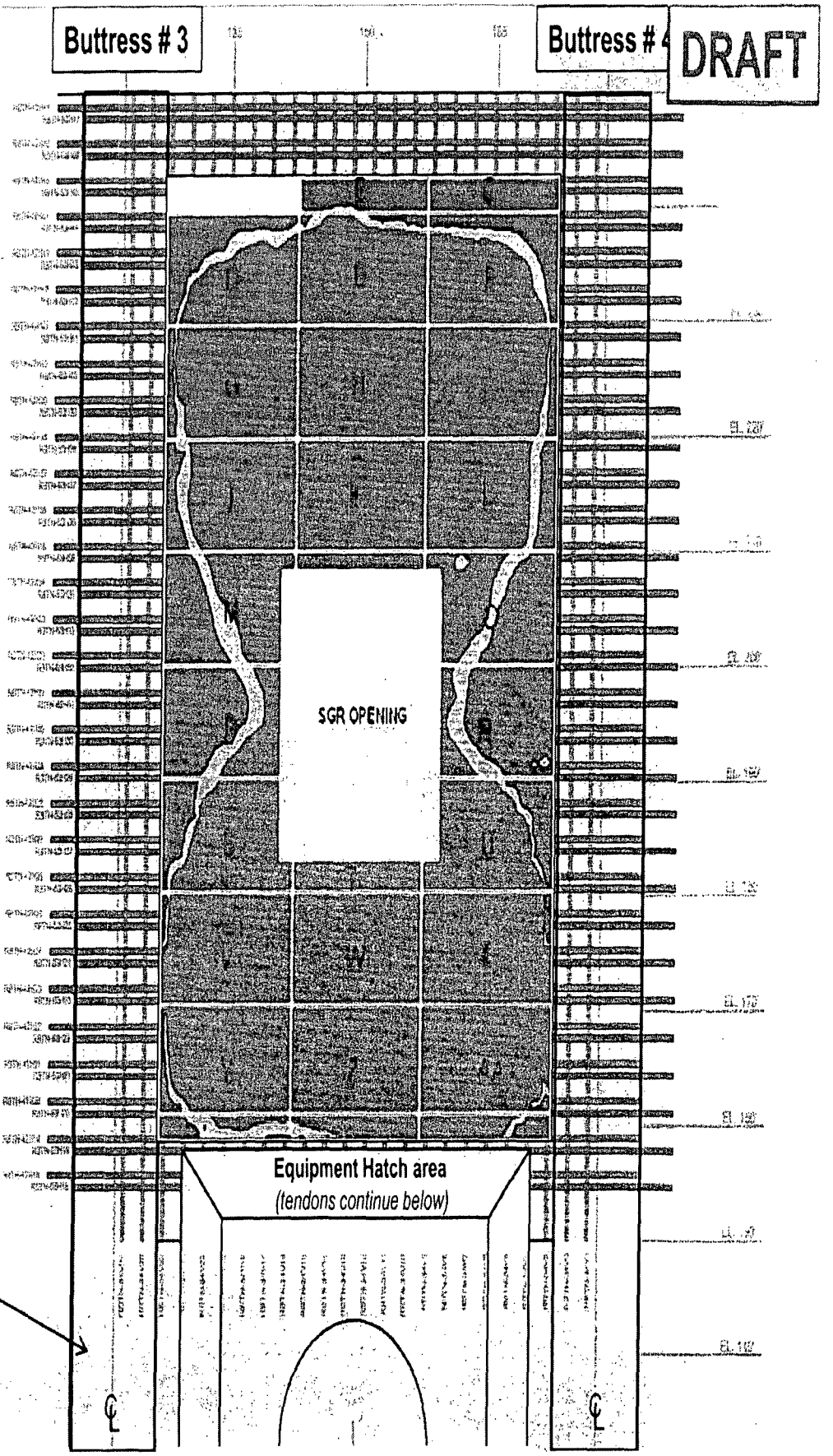
Tendon Pattern at time of cutting SGR Opening

Energized Tendon

Removed Tendon



Wall Section Cutaway

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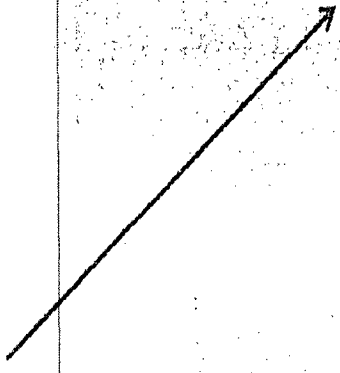
Wall Section at SGR Opening (elevation view)



Source Drawing:
425-033 SH000

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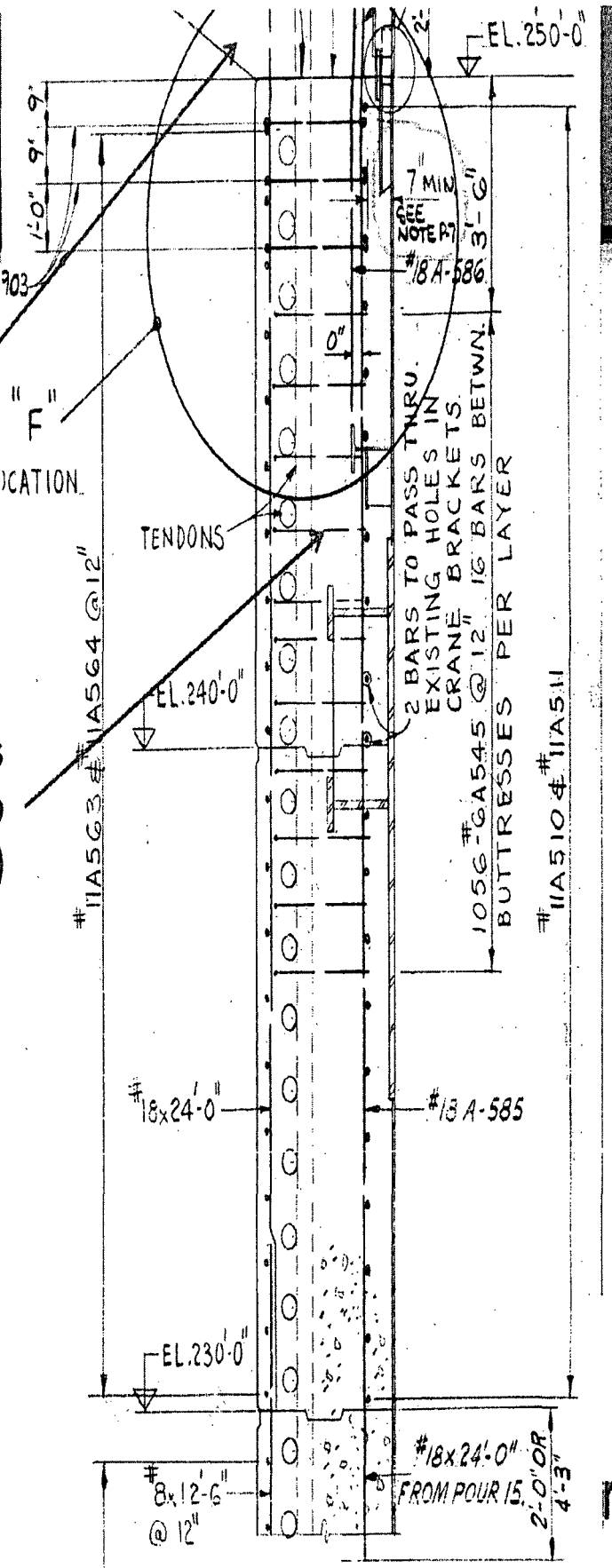
Progress Energy

Wall Section Cutaway (cont)

DRAFT



Bottom of Ring Girder

Wall section at higher elevations showing additional stirrup reinforcement (elevation view)

Source Drawing:
425-033 SH000

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Buttress Cutaway

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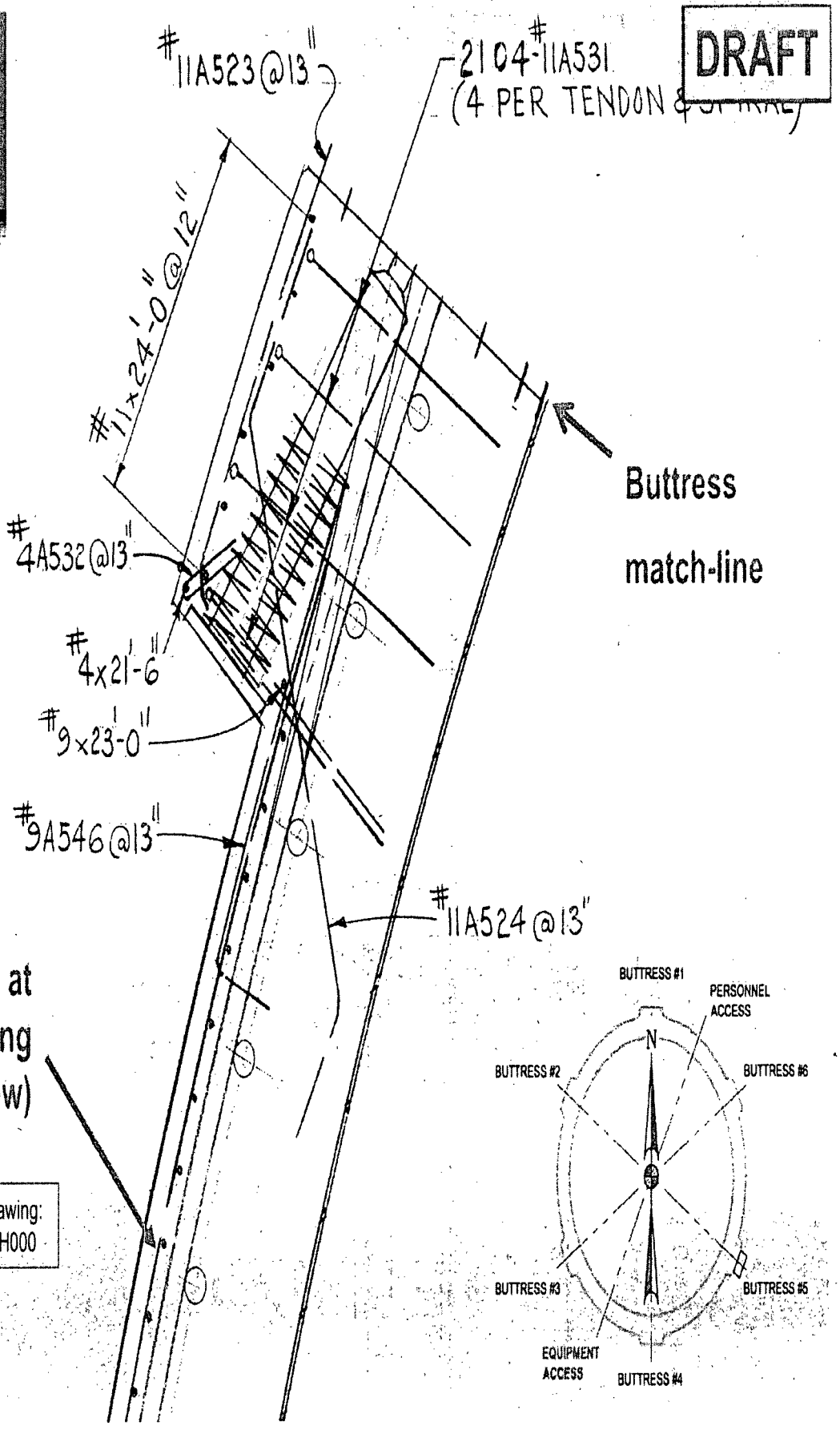

Wall Section at SGR Opening (Plan View)

Source Drawing: 425-033 SH000

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ROOT CAUSE ANALYSIS

Root Cause Analysis – PII Metrics

Un-refuted Failure Modes as of Nov 9th 2009

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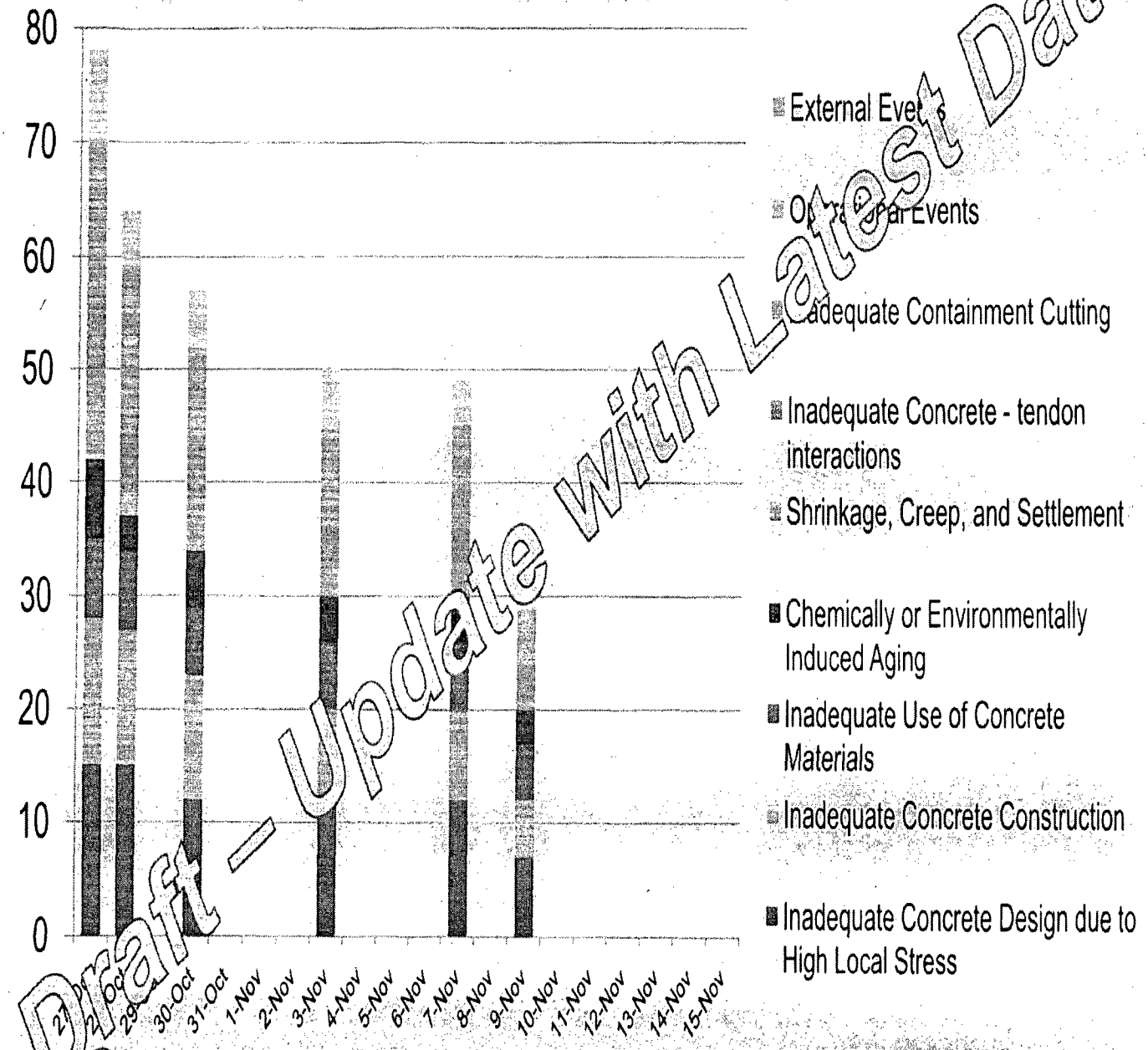

Draft – Update with Latest Data

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Progress Energy

Root Cause Analysis
Field Data Acquisition

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- 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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Progress Energy

Root Cause Analysis
Field Data Acquisition (continued)

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

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Root Cause Analysis
Field Data Acquisition (continued)

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- 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

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OPERATIONAL EXPERIENCE (OE)

Steam Generator Replacement (SGR) OE

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Type of Information Collected from the Industry

- Architect Engineer and Constructor
- Type of Containment and design pressure
- # of Buttresses
- Concrete design strength requirement
- Dimensions
  - Internal containment diameter and wall height
  - Containment cylinder wall and dome thickness
  - Tendons details (# vertical, # horizontal, # dome, strand diameter)
  - Liner thickness
- Reinforcement details
- Whether concrete opening was made
  - Was hydro-excavation used
  - And if so what company performed it
- Detensioning details
  - # by cutting
  - # by relaxation
  - # of tendons removed/detensioned beyond the SGR opening

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Concrete OE

- Worley Parsons – involved with 1976 dome delamination investigation and repair (as Gilbert / Commonwealth)
- Structural Preservation Systems (SPS)
  - Examples
- Wiss, Janey, Elstner, Inc (WJE)
  - Examples

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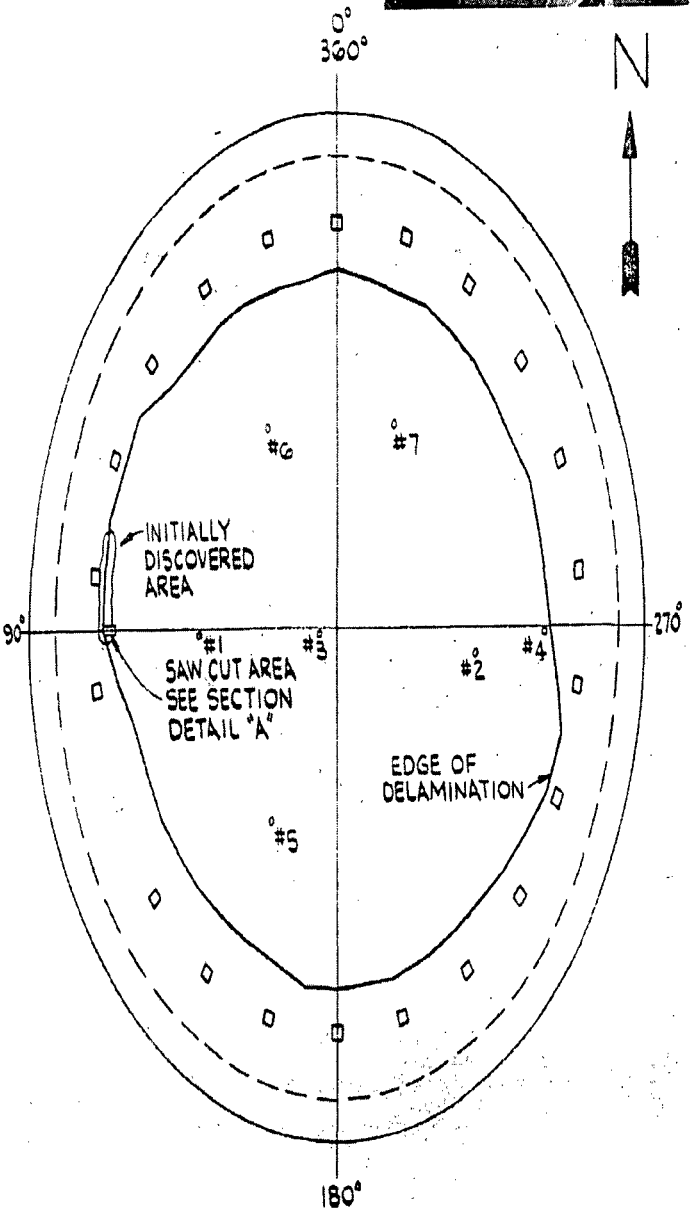
1976 Dome Delamination Cause

- Compression - tension interaction failure occurred
- Contributing Effects
  - Radial tension due to pre-stressing
  - Thermal effects
  - Tendon alignment
  - Stress concentrations
  - Shrinkage
- Combined with biaxial compressive stresses and lower than normal direct tensile strength of concrete



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1976 Dome Delamination
Repair Approach

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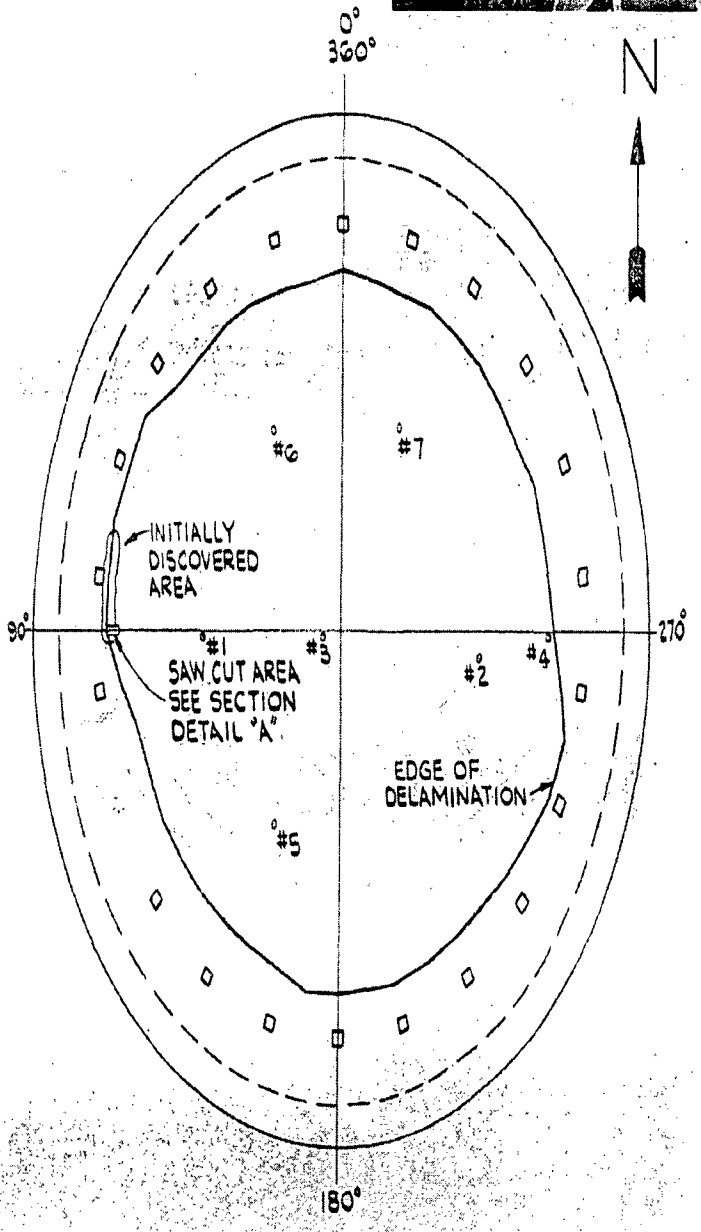
- Tendons detensioned (18)
- Delaminated surface was removed
- Lower level cracks grouted with epoxy
- New reinforcement placed
- New cap poured and cured
- Tendons partially re-tensioned (18)



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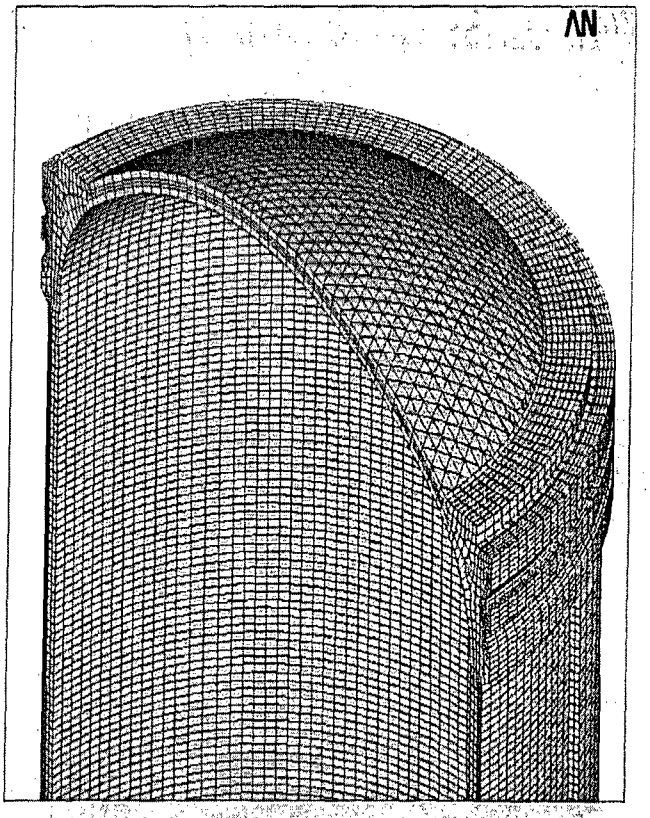
DESIGN BASIS ANALYSIS



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Design Basis

- Reinforced Post-Tensioned Concrete Structure
- 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 (- 6.0 psig)

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CR3 FEA Model

- **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

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Progress Energy

CR3 FEA Model

- **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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Concrete Geometry Based on Gilbert Associates Drawings

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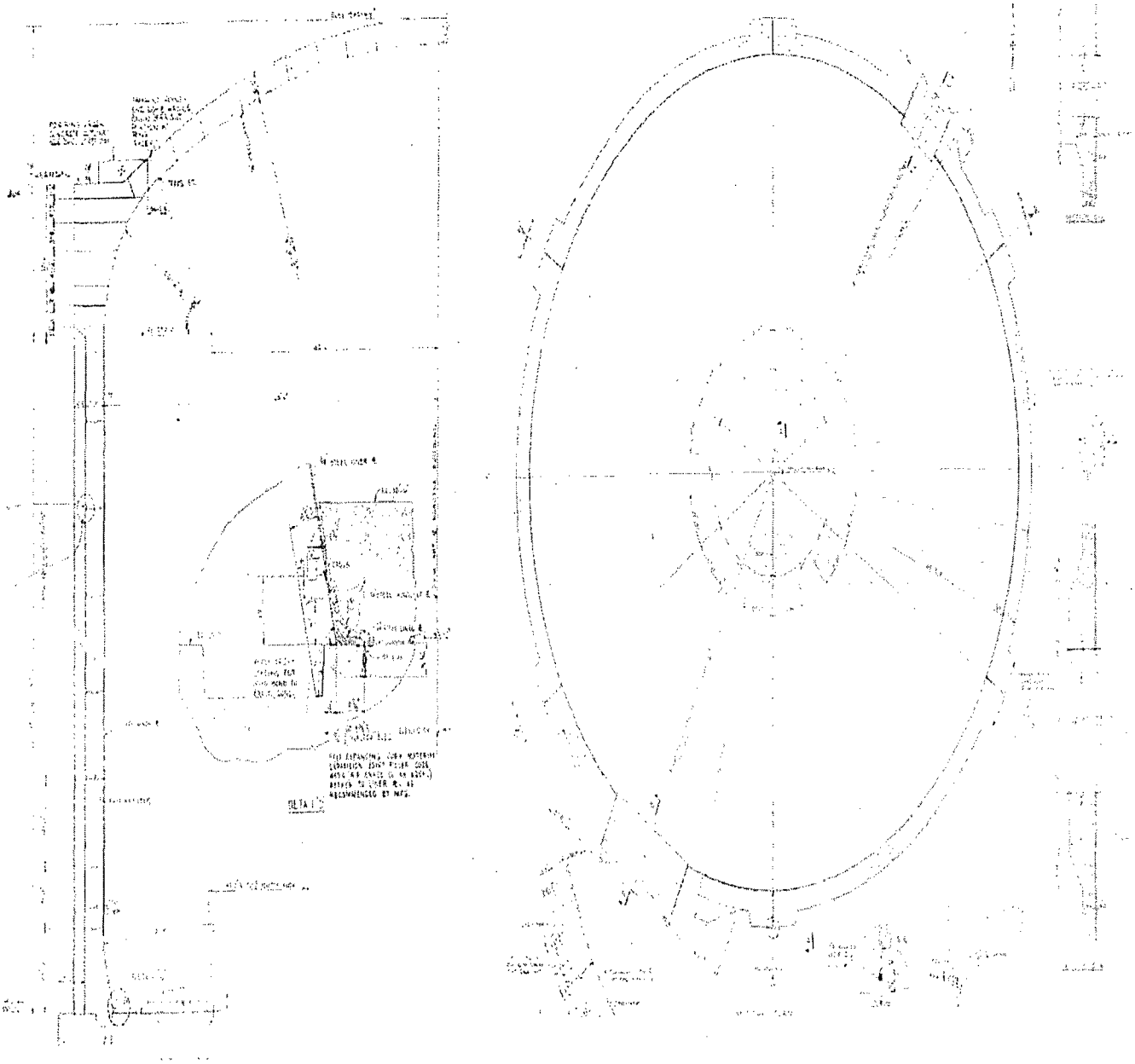

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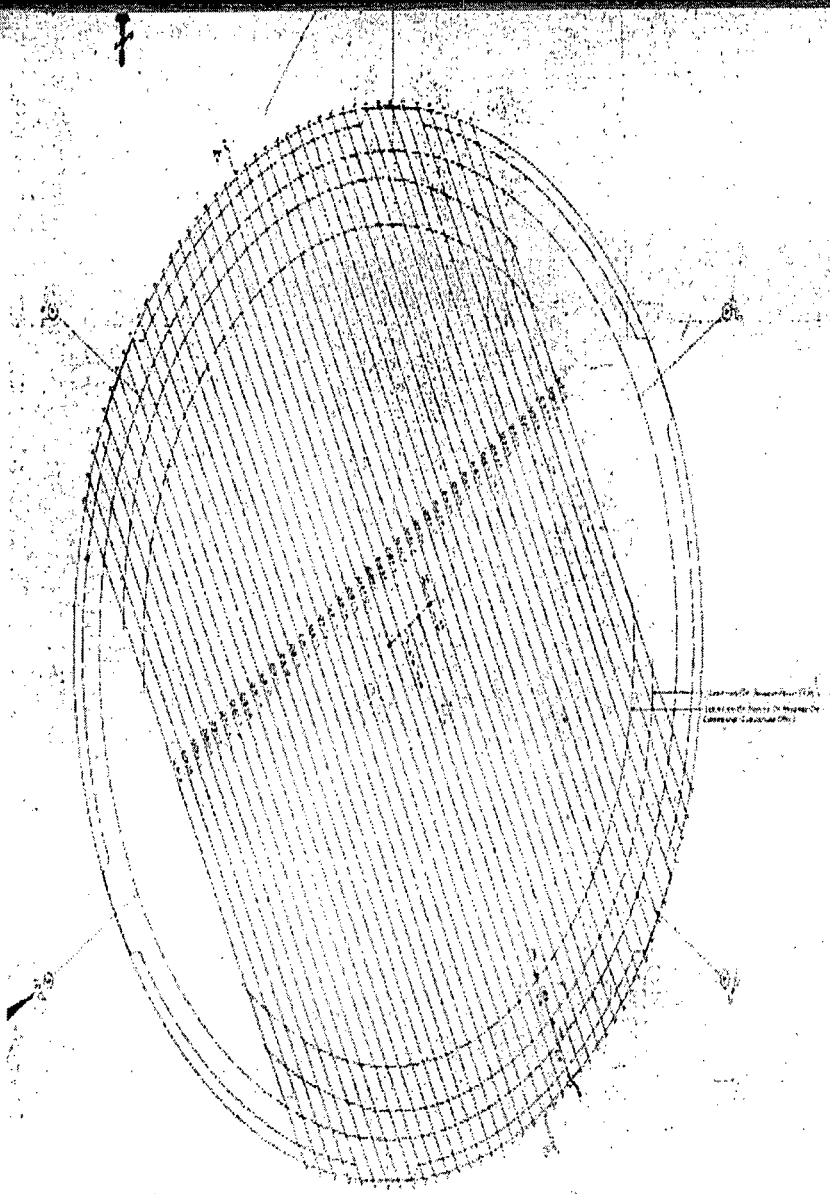
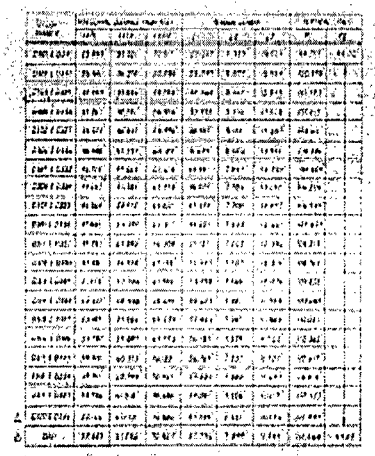
Tendon Geometry Based on Prescon Drawings





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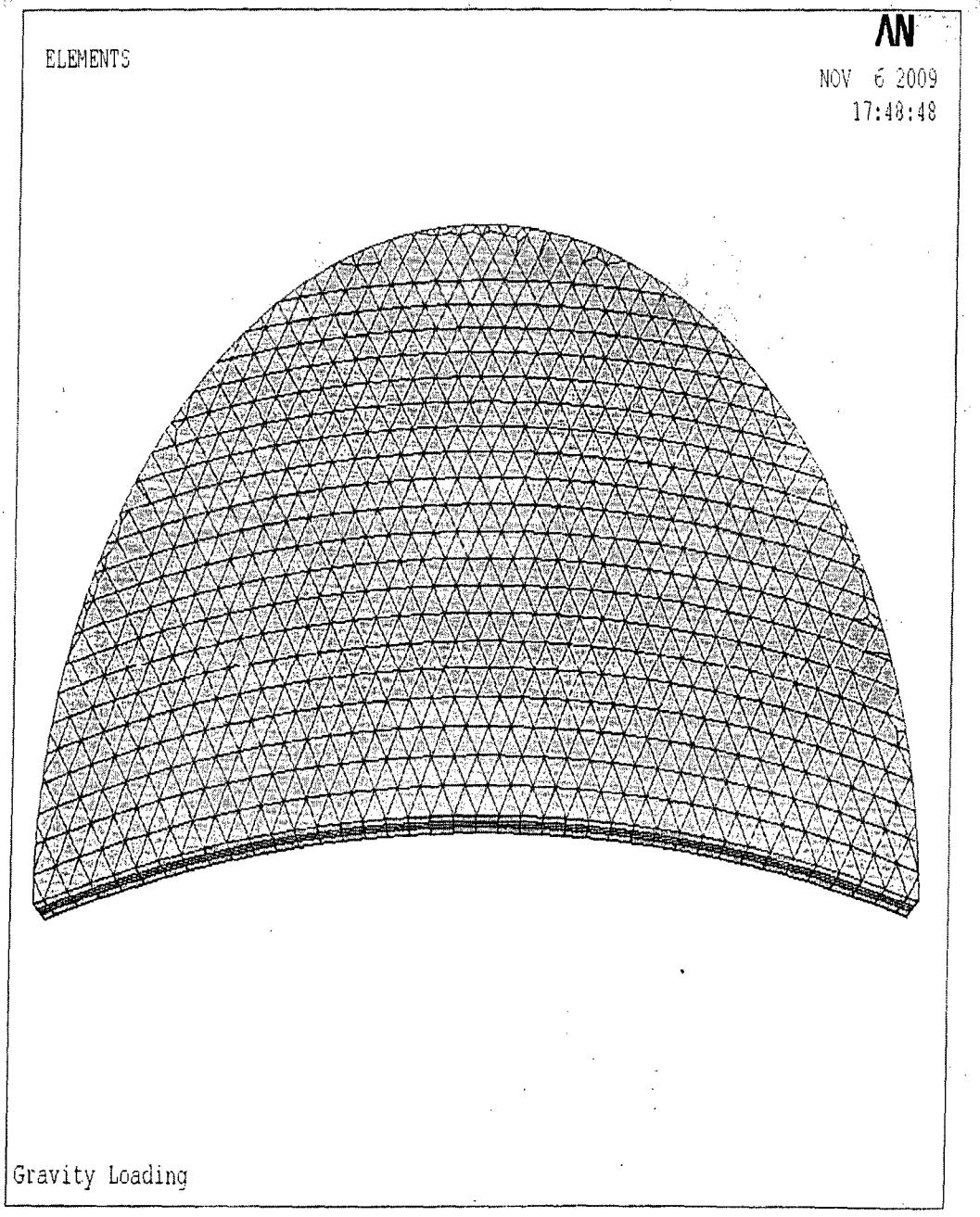
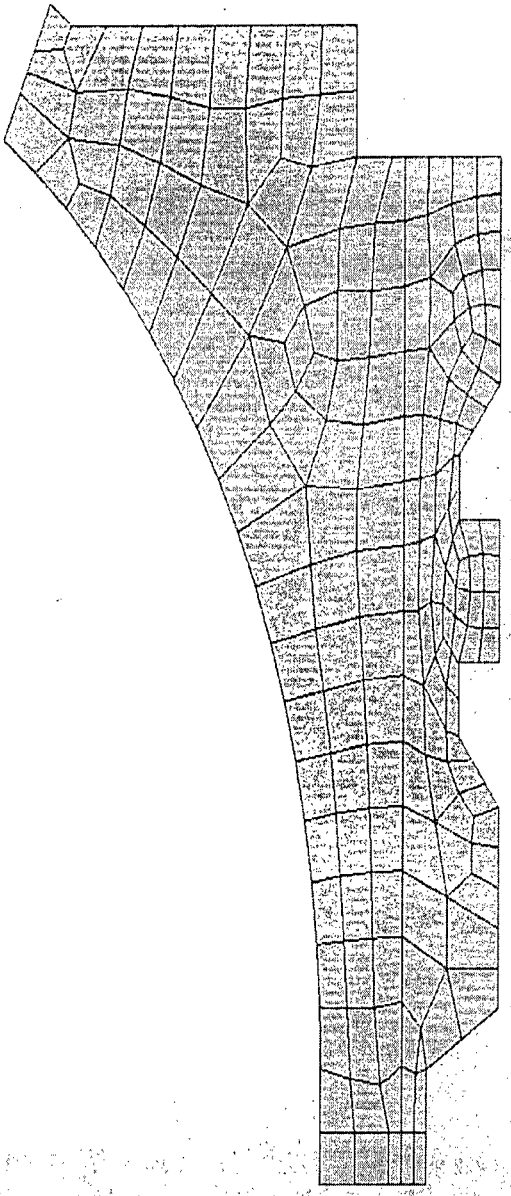
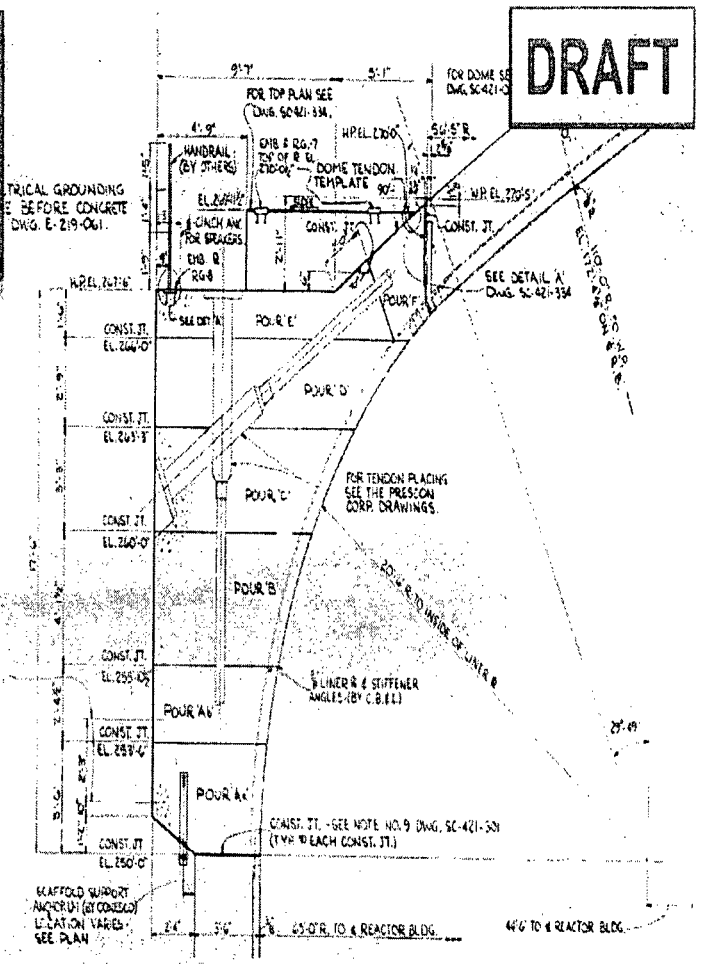
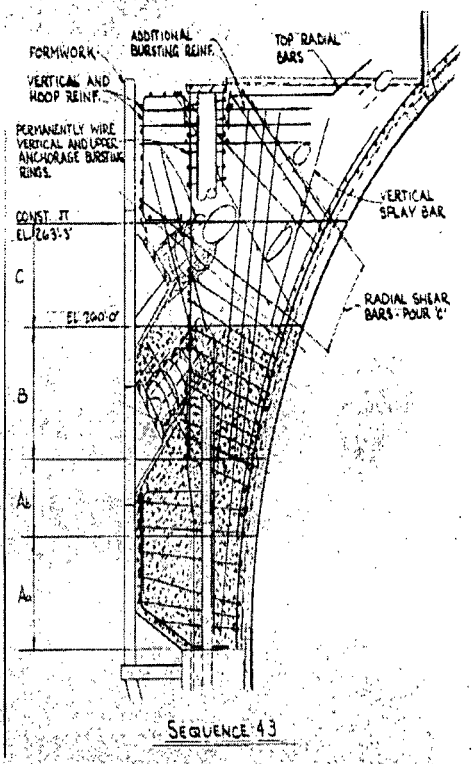
Dome FEA Model



Ring Girder Model







SEQUENCE 43

Core Building Geometry – FEA Mesh
Hoop Tendon Locations Defined

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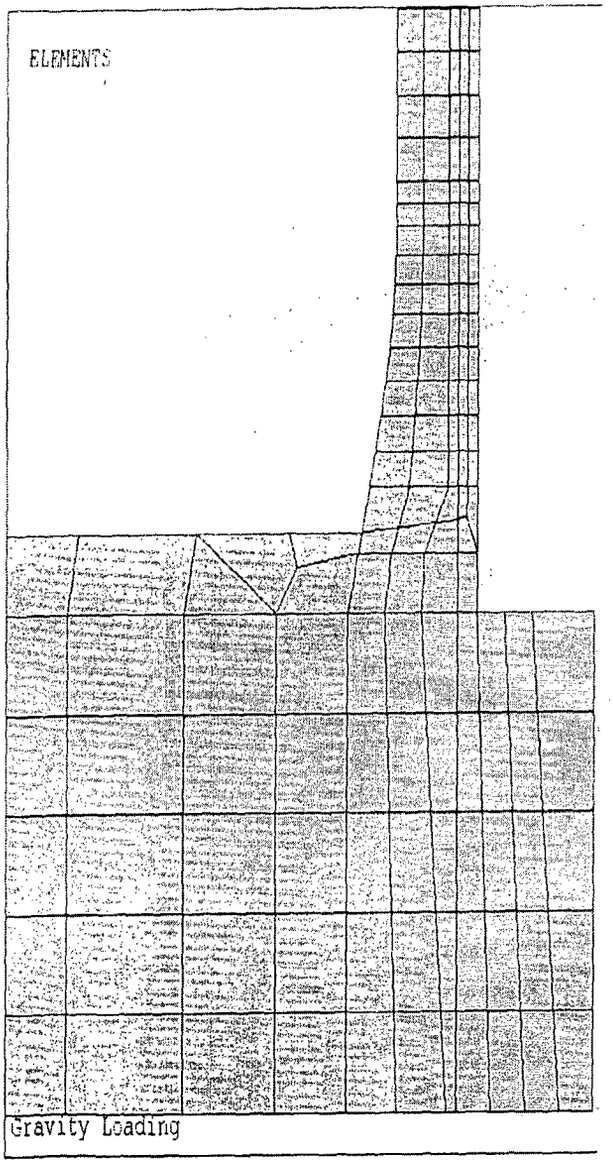
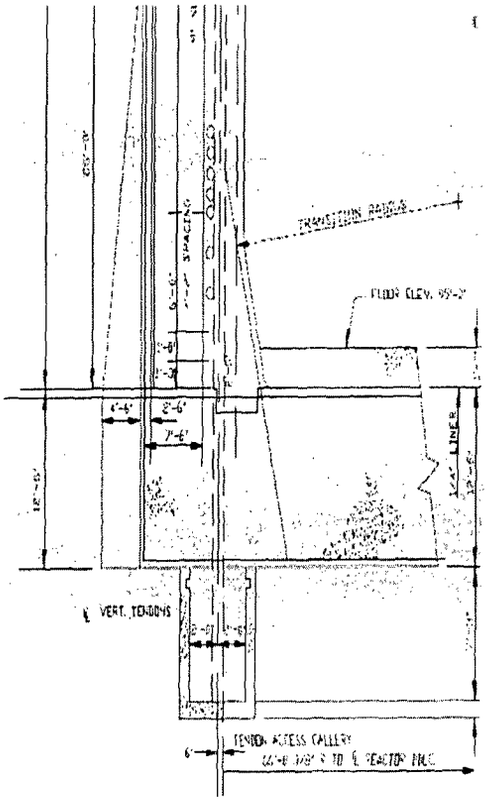
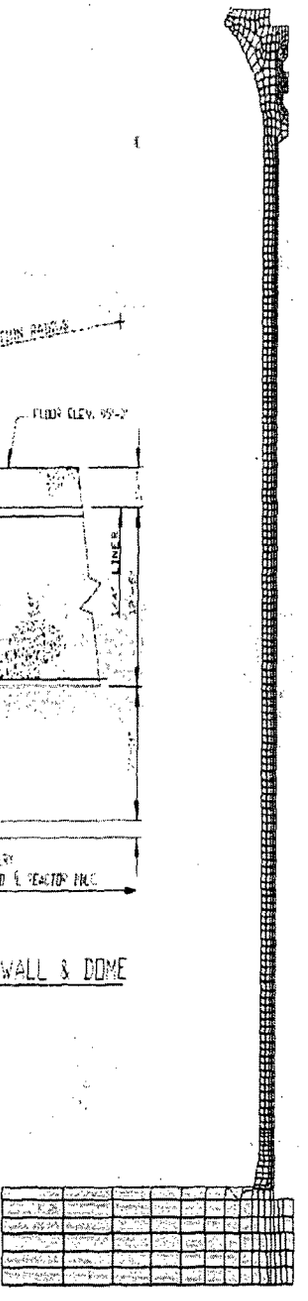




TYPICAL SECTION THRU WALL & DOME



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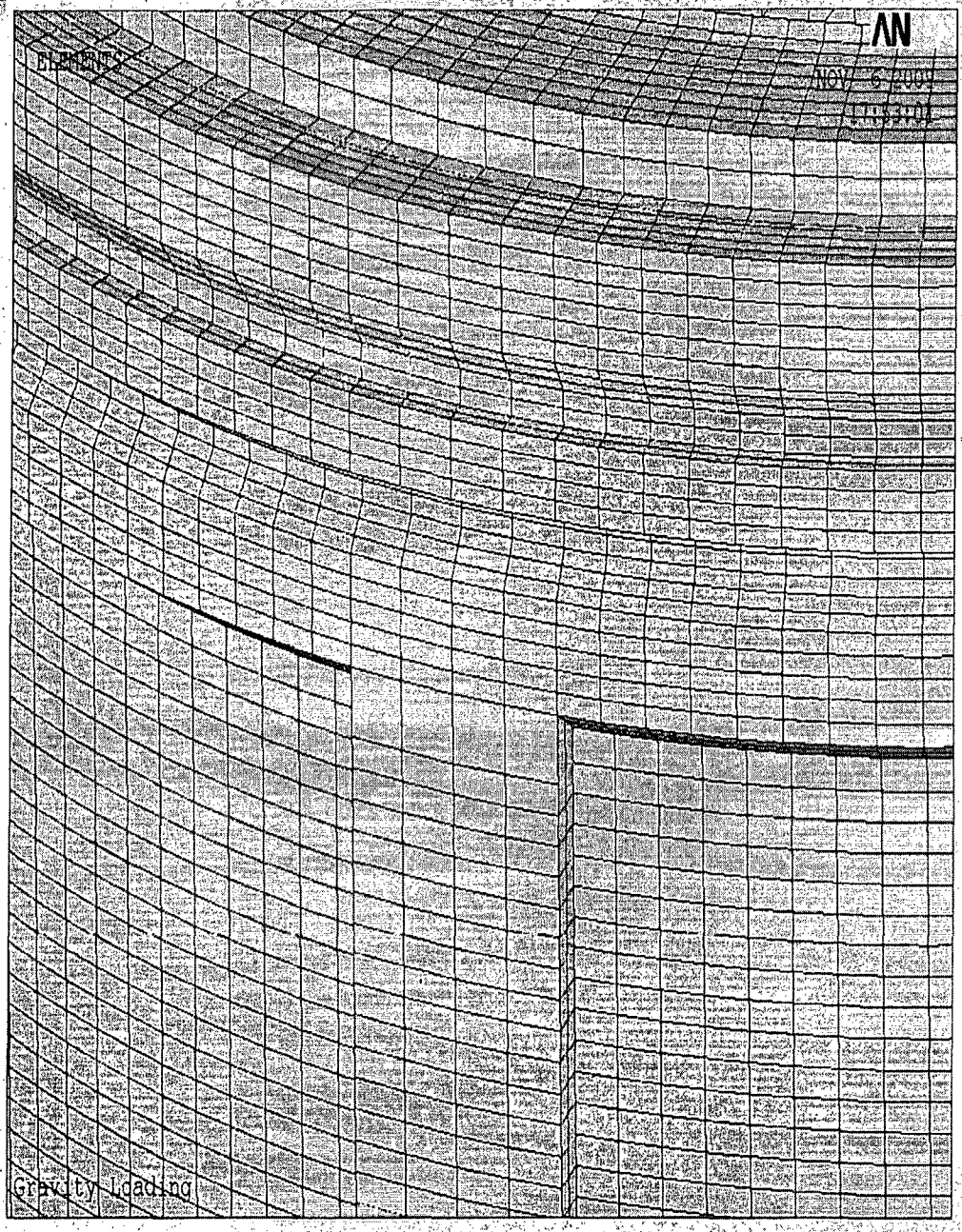
Core Building Geometry - Buttresses



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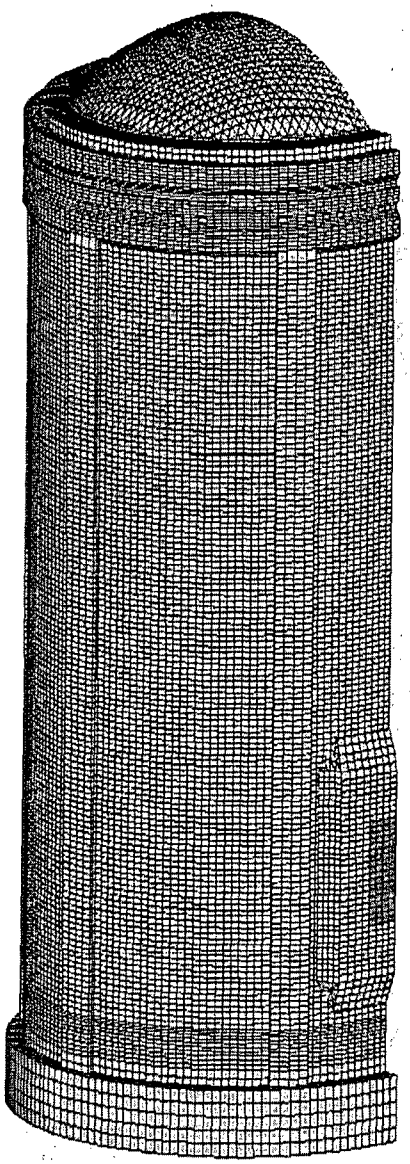
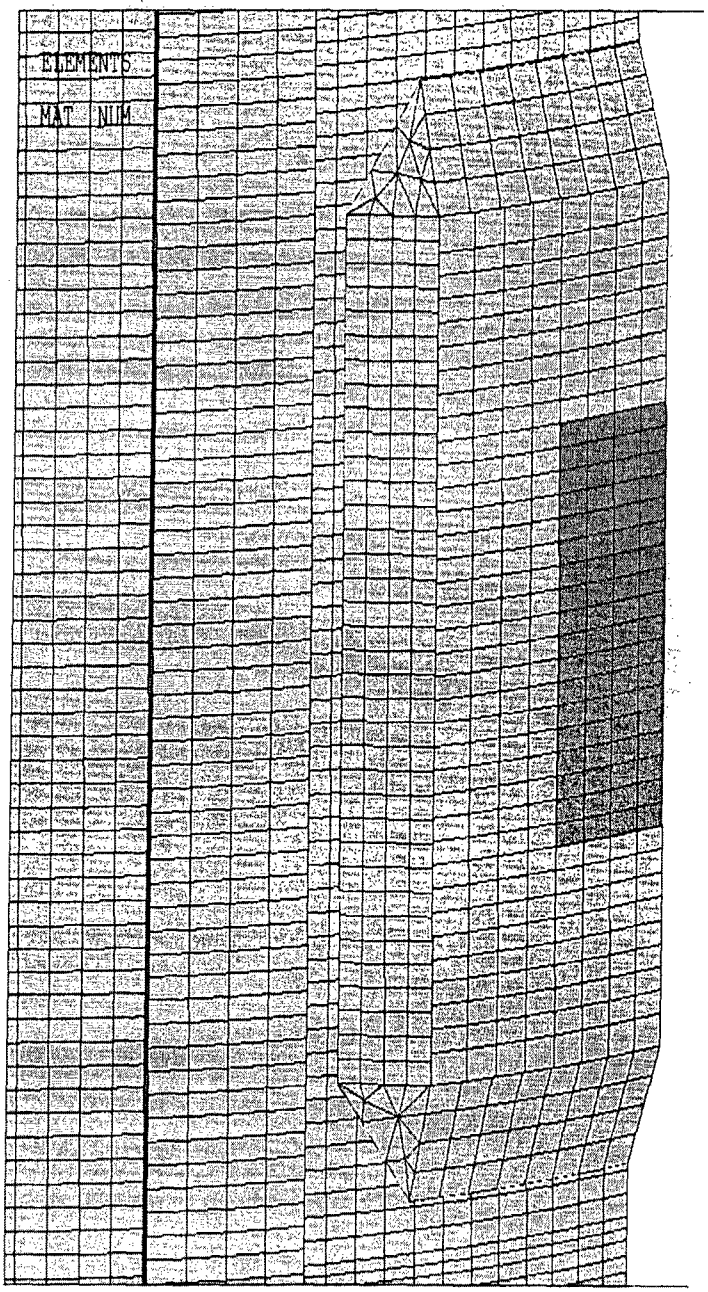
Equipment Hatch Model





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Liner

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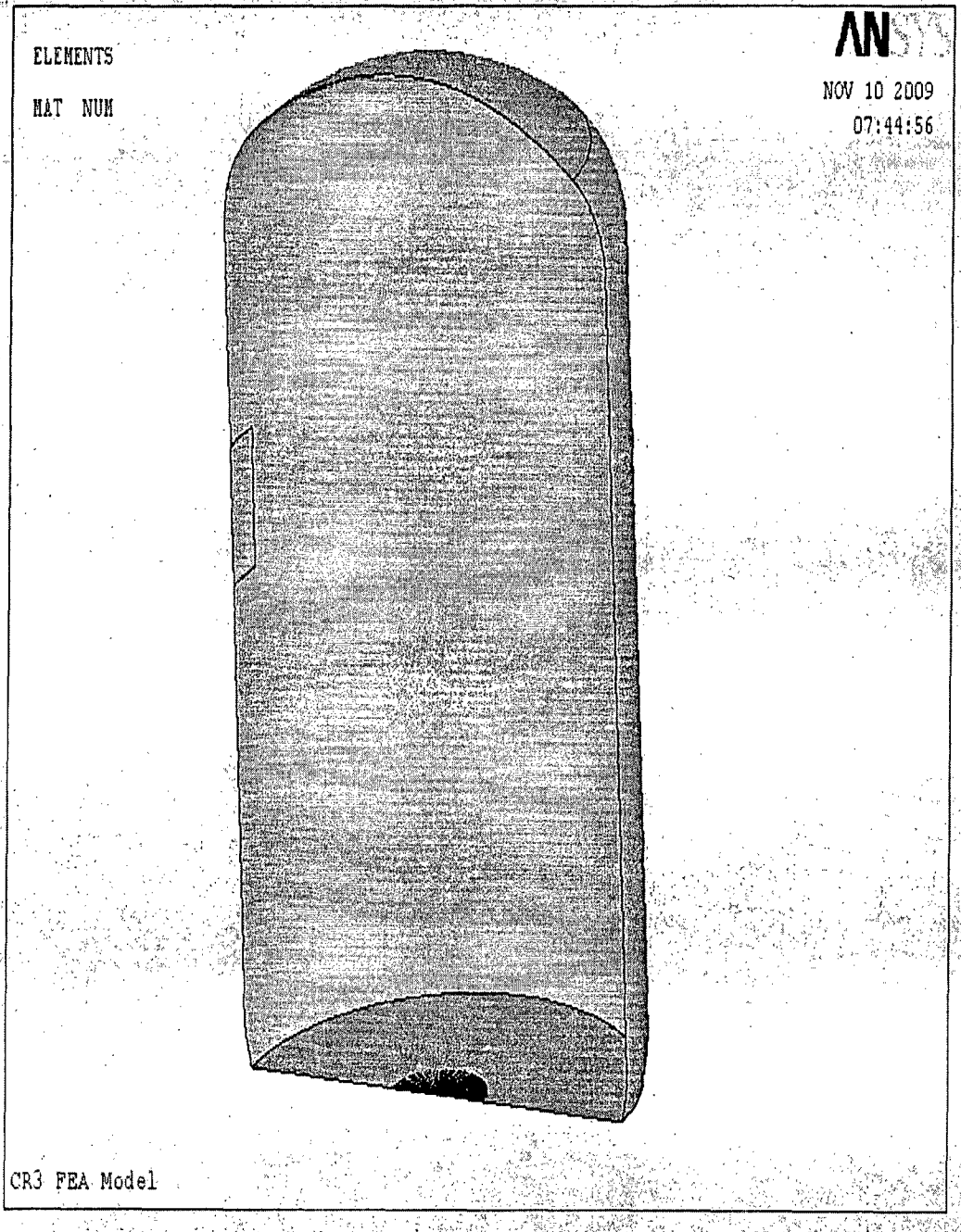

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Tendon Loading

- The tendons are preloaded to a prescribed load magnitude.
- The application of the tendon loads is achieved in the analysis using initial strain input
- An empirical formula has been developed to account for the loss of load as the distance from the anchor point increases:

$$P = P_0 \, e^{-(ma + ks)}$$

  - Where:
    - P_0 = preload magnitude
    - m = friction coefficient
    - a = inflection angle (0.16)
    - k = wobble coefficient (0.0003)
    - s = distance from anchor point

  - Tendon preloads used in analysis:
    - $P_{0\text{-dome}}$ = 1635 Kips (1,215,000 lb. 40 years)
    - $P_{0\text{-horizontal}}$ = 1635 Kips (1,252,000 lb. 40 years)
    - $P_{0\text{-vertical}}$ = 1635 Kips (1,149,000 lb. 40 years)

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Dome Force Vectors Ported to Global Model

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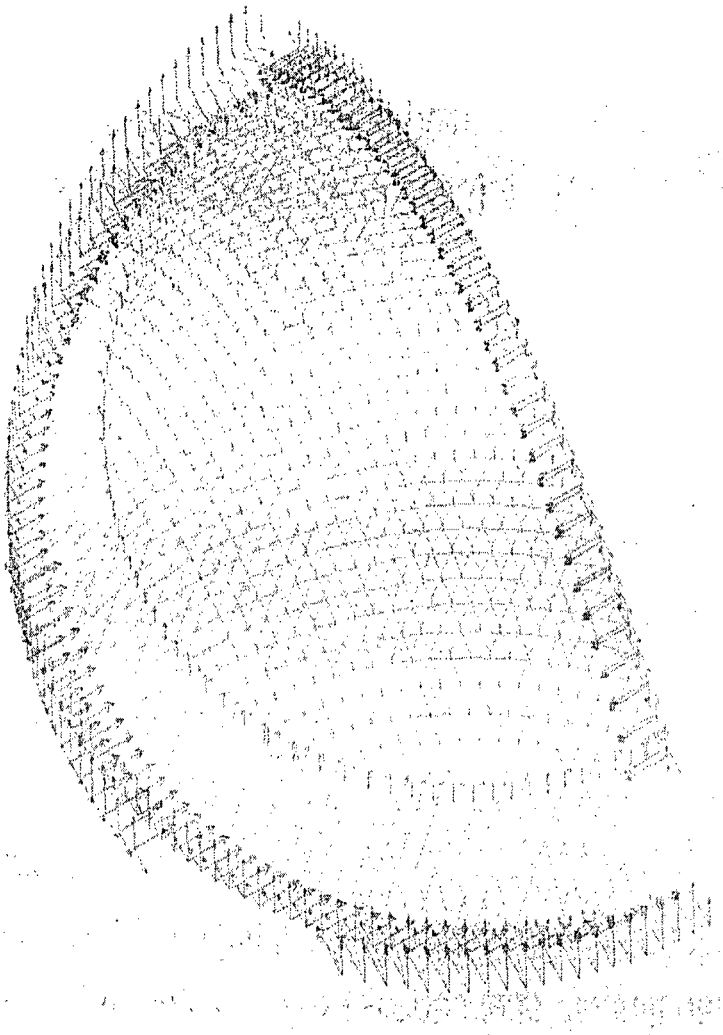
Civil



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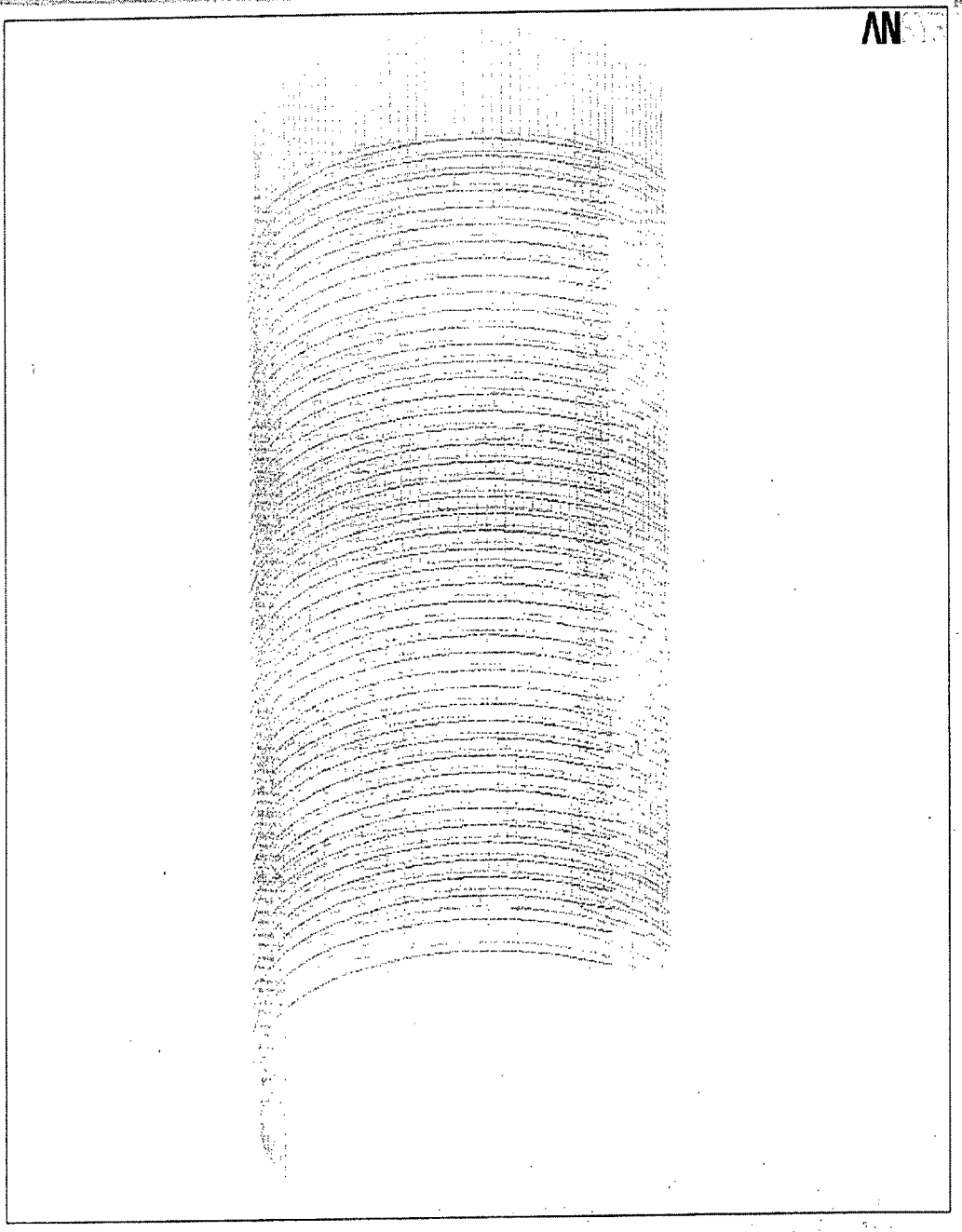
FEA Model – Vertical and Hoop Tendons



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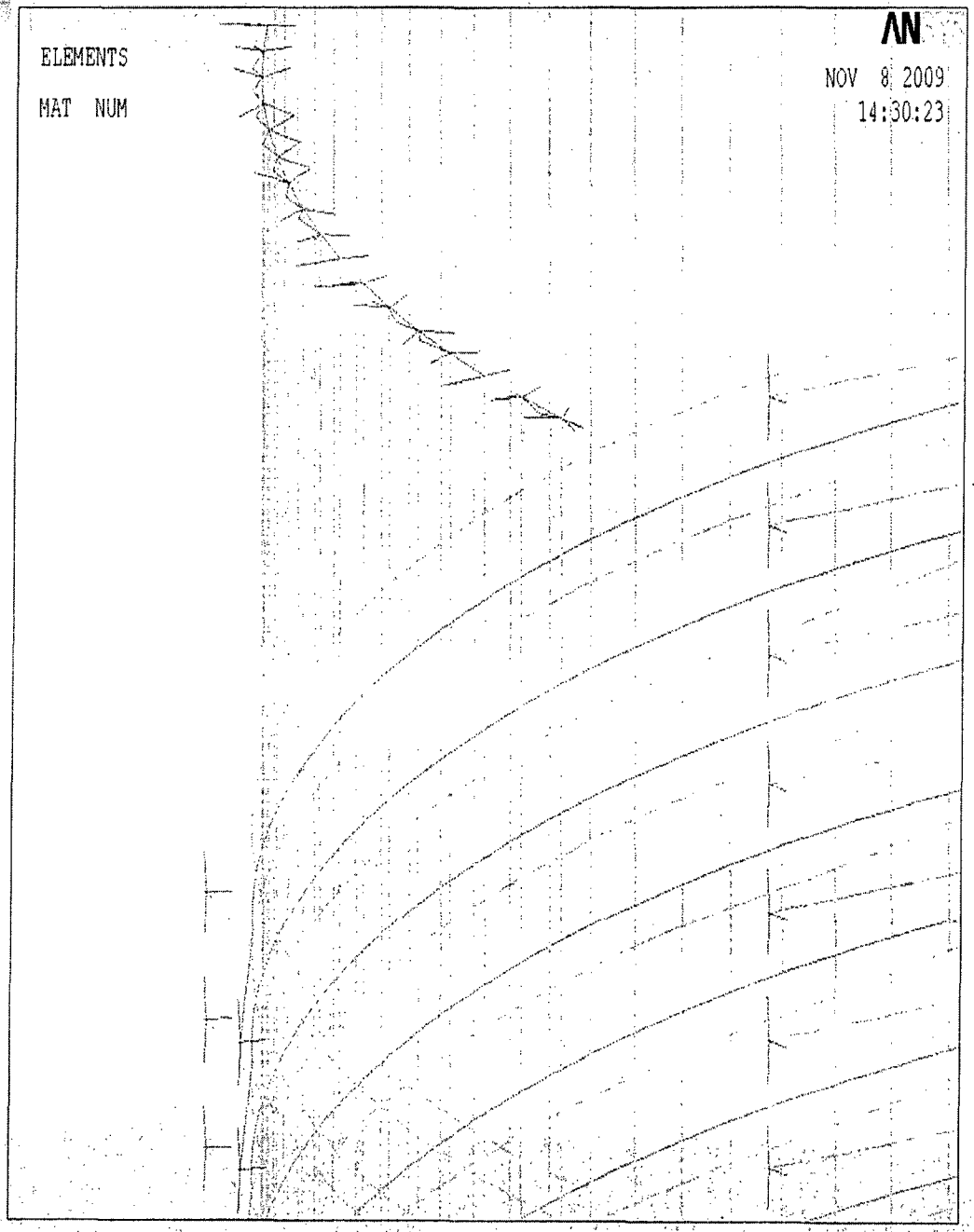
FEA Model – Vertical and Hoop Tendon Supports



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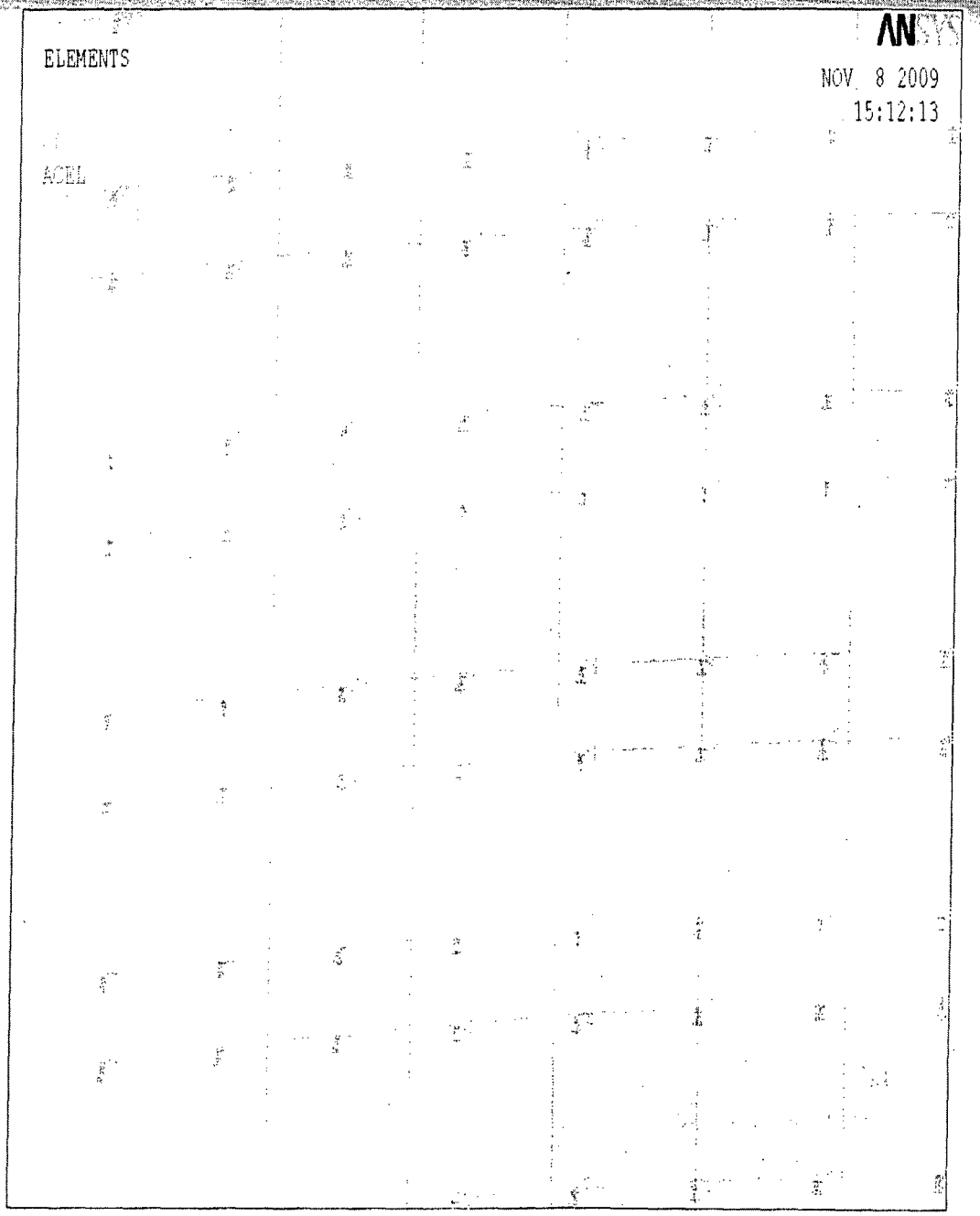
FEA Model – Hoop Tendons Couples and Supports



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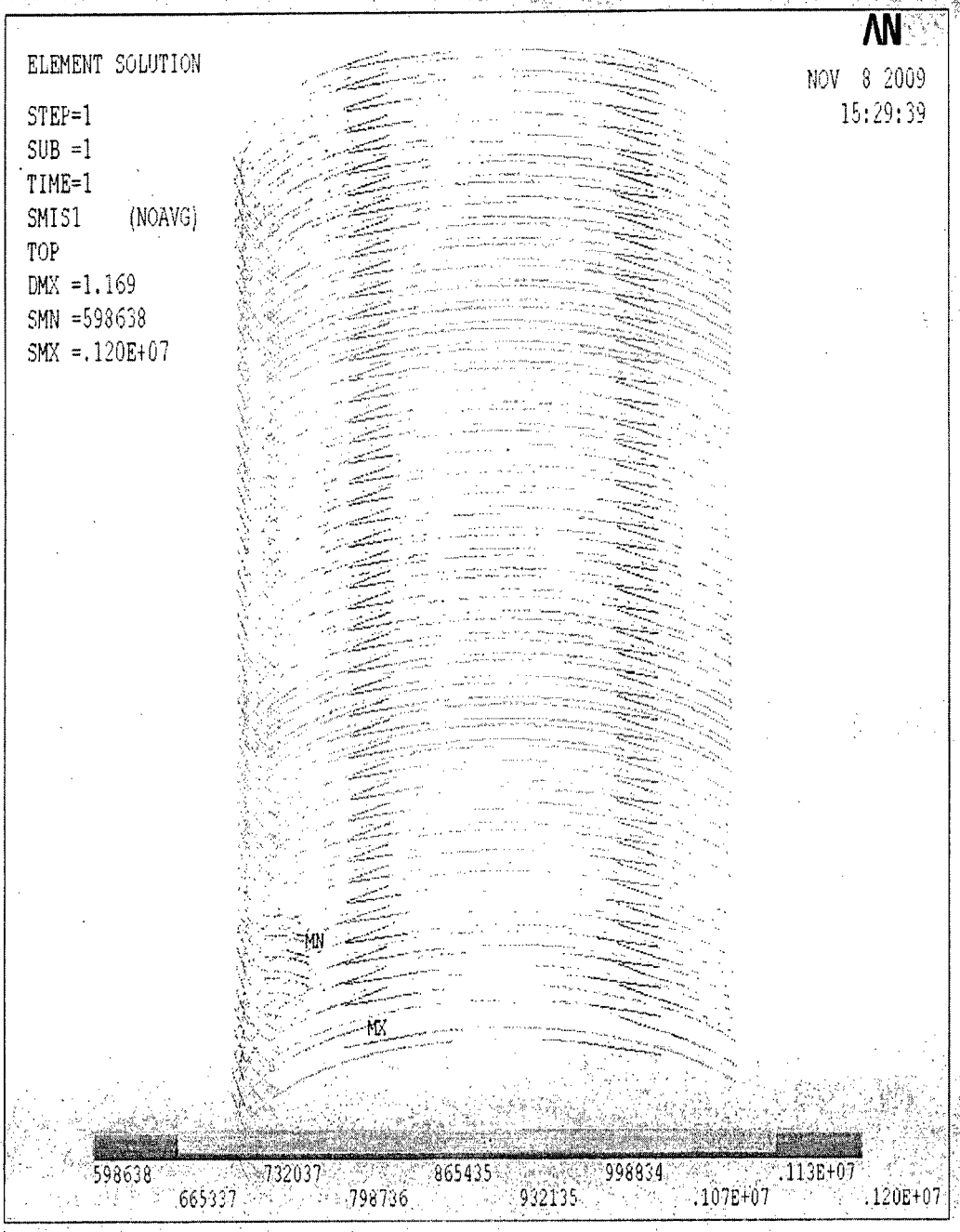
Hoop Tendon Forces



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Planned Analysis

Existing Design Cases for Comparison

- Gravity (.95 G)
- Internal Dead Load (200 psf)
- Tendons (1635 kips / tendon)
  - Include losses
- Internal Pressure (55.0 psi)
- Wind Pressure (0.568 psi)
- Seismic
- Accident Thermal

Planned Analysis Steps

- 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 and repair may be adjusted

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Design Basis Controlling Load Steps

- Restart the Re-tensioned Model and solve the following Controlling Load Steps
  - 1.5 Internal Pressure + Accident Thermal
  - 1.25 Wind + 1.25 Pressure + Accident Thermal
  - 1.25 Earthquake + 1.25 Pressure + Accident Thermal
  - 2.0 Wind + Pressure + Accident Thermal
  - SSE Earthquake + Pressure + Accident Thermal
- Run Comparison to original building elastic design results to show repair has restored building to original condition

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Preliminary Comparison of FEA Results to Extent of Condition Measurements

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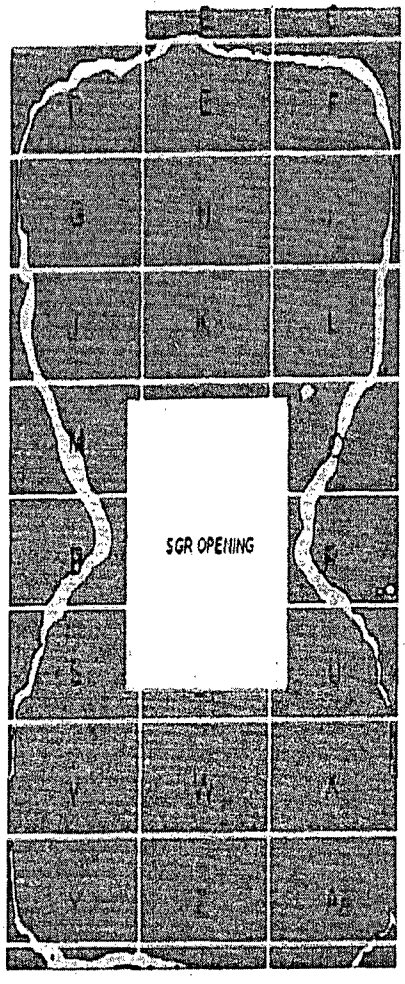
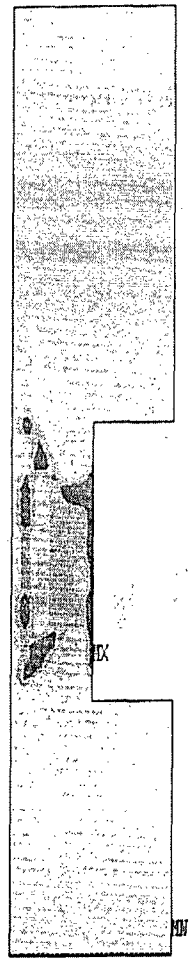
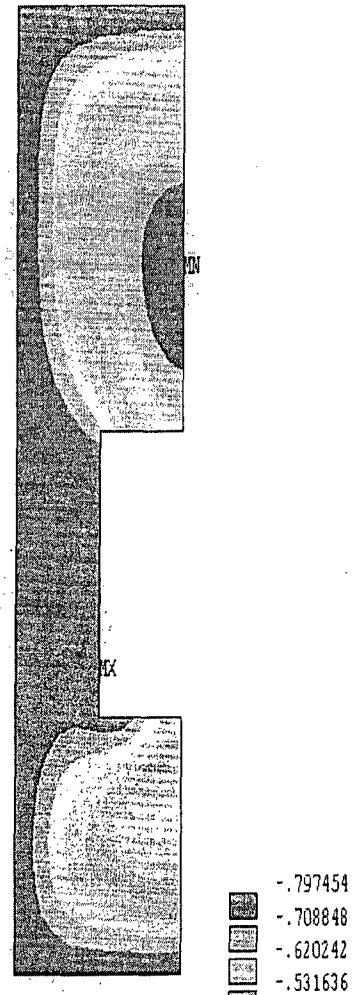
NDE Measurements
(figure not to scale)



Calculated Gap Status
behind Delamination



Calculated Displacements



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REPAIR APPROACH

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Repair Attributes

- Incorporates and is compatible with Root Cause Analysis findings
- Restores applicable design basis margins
- Incorporates Life of Plant Considerations
  - Long Term Surveillance and/or Maintenance Requirements
  - License Renewal
- Constructability

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Repair Alternatives Considered

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

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Simplified Overview of Engineering & Repair Workflow

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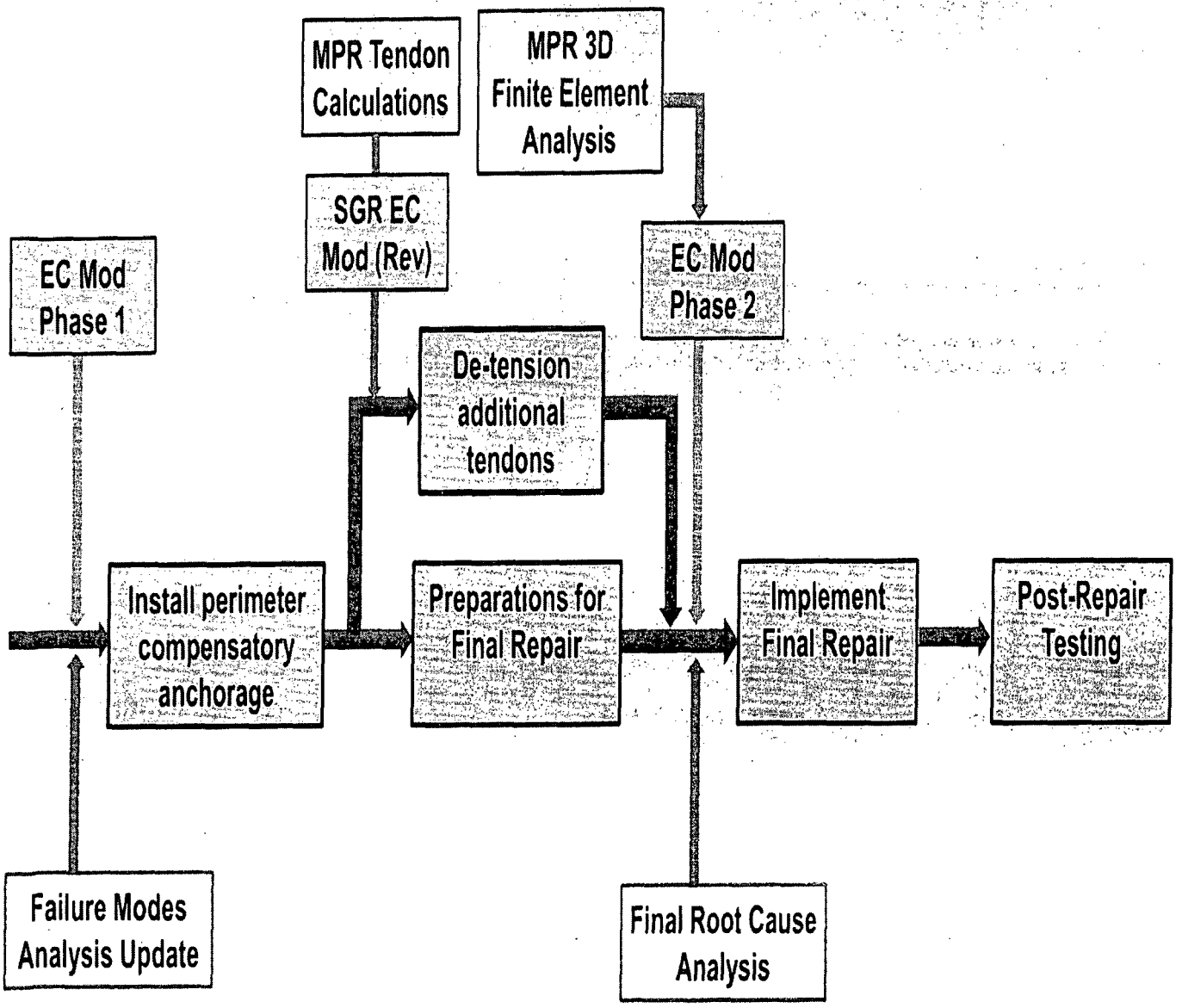
Tentative – Subject to RCA and DBA Results



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Perimeter Anchorage

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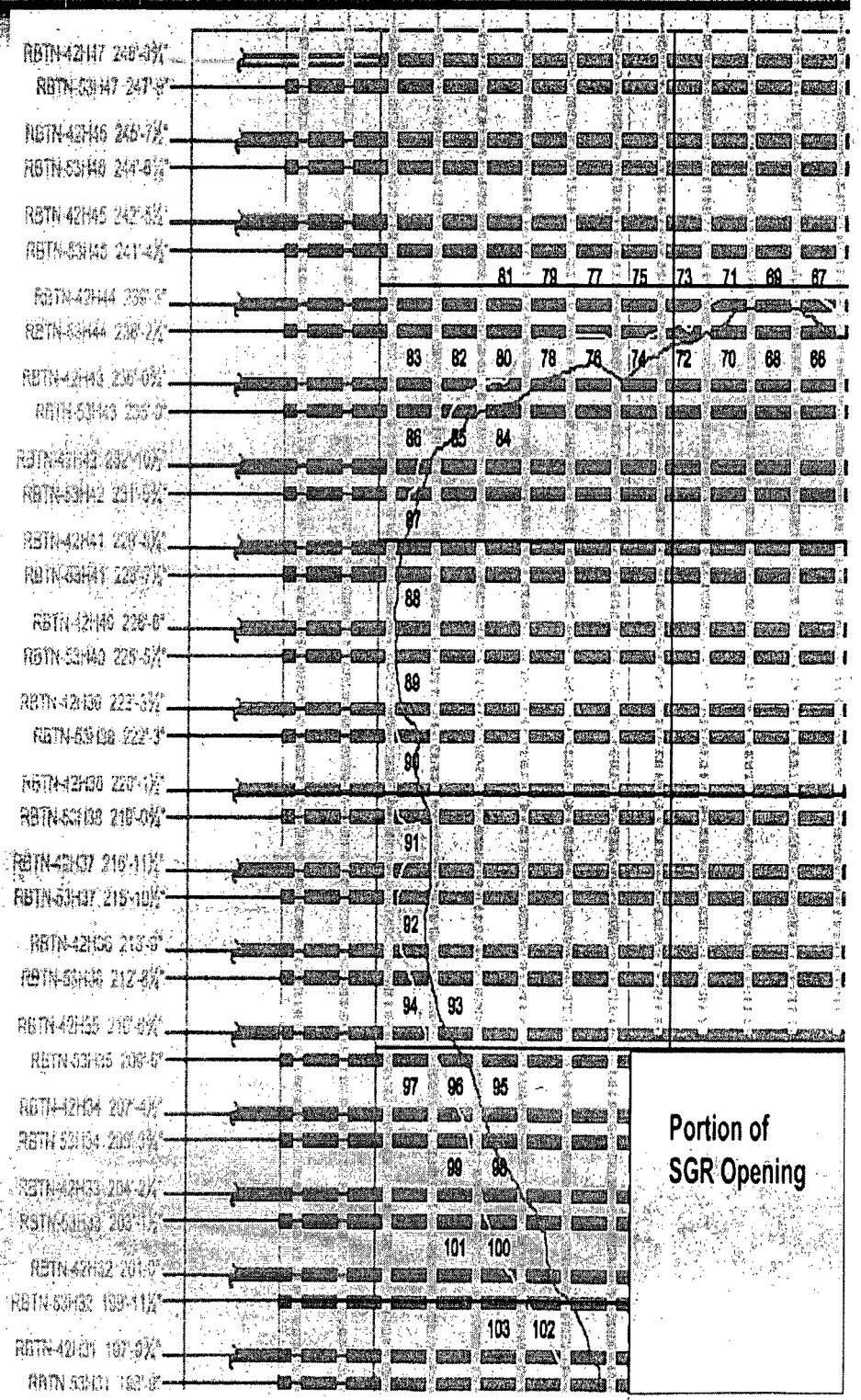
Image is a portion of delaminated area to show planned perimeter anchorage pattern for stabilization

XX Perimeter anchors to stabilize delamination before additional de-tensioning proceeds



Drawing is preliminary

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Post- Repair Testing

- Approach - ILRT and System Pressure Test
- ASME Section XI IWE for the liner and IWL for the concrete
- Concrete exterior will be visually examined prior to pressurization and following de-pressurization
- Evaluating other additional instrumentation based on the final repair that is implemented, and as driven by:
  - Root cause analysis
  - Design basis analysis (3D FEA Model)
- Additional NDE is required for restored liner plate

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Stakeholder Interactions

- Prompt Notification of Regulator & Industry
- Engagement of Critical Industry Organizations
  - NEI Energy Institute (NEI)
    - Including Nuclear Safety Information Advisory Council (NSIAC)
  - Institute for Nuclear Power Operations (INPO)
  - Electric Power Research Institute (EPRI)
- Continued Transparency with Regulator
  - Special Inspection Team (SIT)
  - Region and NRR/RES technical discussions
- Periodic Updates with U.S. Licensees
- Public Outreach
  - Dec 2009 Public Meeting in Crystal River area

NGG

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Questions