

Constellation Demonstration Augmented Containment Inspection

Workshop on Nuclear Plant Life
Extension Research and Development

Tom Esselman
Principal, Lucius Pitkin, Inc.

February 22, 2011



Lucius Pitkin, Inc.

Consulting Engineers

Objective

- ▶ Prepare a Containment Inspection Guide to support operation beyond 60 years.
- ▶ Obtain information on containment integrity from the Ginna and Nine Mile Point plants.

Program Activities

- ▶ Program activities are selected to:
 - Demonstrate a linkage between a degradation mechanism that may occur and inspections or tests that are to be performed.
 - Provide inspections and tests that are quantifiably reproducible over a 40 year period.

Scope

- ▶ The scope includes concrete and other materials associated with a containment function.
 - Concrete containment structures including reinforced, pre-stressed, and post-stressed systems.
 - Tendons including wires, anchorages, shims, etc.
 - Drywell/torus/suppression pool.
 - Basements and foundations of the containment.
 - Concrete structures inside the containment.
 - Structural members housed within the concrete (RCS supports, embeddings, etc.).
 - Containment liner, penetrations, and attachments.

Concrete Degradation Mechanisms

Degradation Mechanisms	Stressor	Effect	Augmented Tests Or Inspections At Ginna
Local Loss Of Moisture	Chronic Intermediate Temperature Exposure (>200°F)	Reduced Elastic Modulus and Rupture Strength	Measure strain near penetration. Measure concrete temperature at time of DIC.
Radiation Damage	Gamma Radiation (>10 ¹⁹ Rads)	Effects Cement Paste By Radiolysis Of Water. Reduction In Strength.	None proposed.
	Neutron Radiation (>10 ¹⁹ N/Cm ²)	Swelling of Aggregates. Reduction In Strength.	None proposed.
Leaching Of Calcium Hydroxide (Seen As Efflorescence)	Exposure To Water Through Cracks (Depends On Temperature And Chemistry)	Diminished Strength Of Cement Paste And Reduced Concrete Strength. Lowered pH And Subsequent Breakdown Of Protective Film On Rebar.	No augmented testing proposed. Latest inspection did not show any active areas of leaching or efflorescence. If detected in the future, samples could be collected and tested.
Chemical Attack	Magnesium And Sulfates Of Potassium, Sodium, And Magnesium.	Swelling Causing Cracking And Spalling, Leading To Reduced Strength.	None Proposed.
	Acids	Increased Porosity And permeability, Reduced Alkalinity	None Proposed.

Concrete Degradation Mechanisms

Degradation Mechanisms	Stressor	Effect	Augmented Tests Or Inspections At Ginna
Alkali-Aggregate Reaction	Some Constituents Of Aggregate Are Reactable In The Presence Of Moisture, With Chemical Compounds Present In Cement, Mostly Alkalis But Also Includes Potassium, Sodium, And Calcium Oxides.	Expansive Stresses And Severe Cracking	No augmented testing proposed. This is effectively covered by visual examination of outside surface in the existing IWL/IWE exams.
Carbonation	Carbon Dioxide From Air Reacts With Calcium Hydroxide In Cement In The Presence Of Moisture Producing Calcium Carbonate	Reduced pH, Rebar Corrosion	Carbonation test on containment exterior wall.
Abrasion	Heavy Load Traffic Exposure To Strong Wind Exposure To Turbulent flow And Cavitation	Pitting, Loss Of Cement And Aggregate Exposure	No augmented testing proposed. This is effectively covered by visual examination of the outside surface of the Containment in existing IWL.

Concrete Degradation Mechanisms

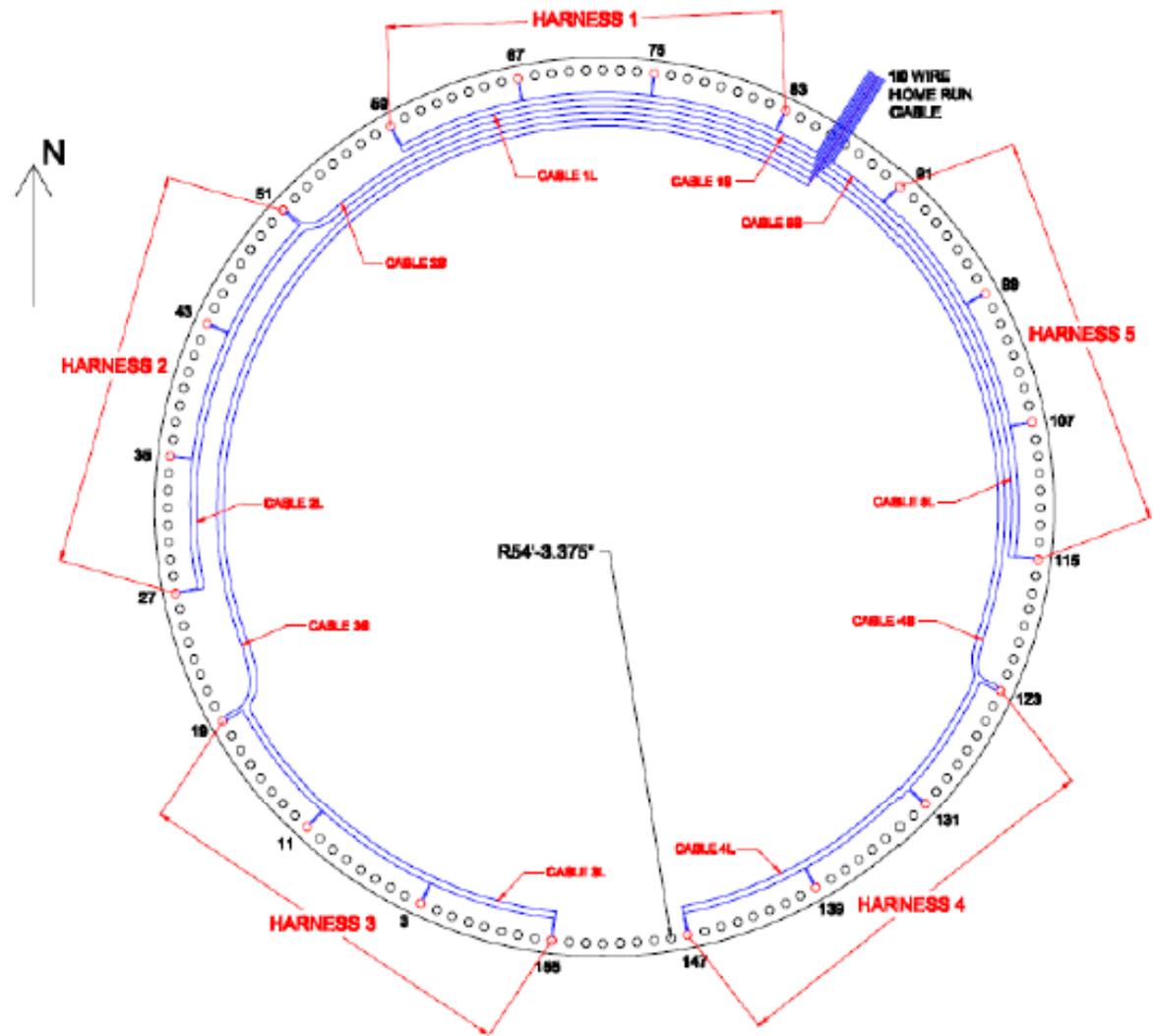
Degradation Mechanisms	Stressor	Effect	Augmented Tests Or Inspections At Ginna
Creep (Mostly In Prestressed Concrete)	High Loading Such As Under Tendon Anchors, High Temperature Such As Near Penetrations, Changes Of Moisture In Concrete	Cracking Along Cement/Aggregate Boundary And Continued Strain Under Constant Load Causing Loss Of Prestress.	Monitor tendon loads by strain gages. Measure strain at penetration.
Fatigue	Cyclic Loading, Including Loads From ILRT	Concrete Cracking And Creep Tendon Relaxation Loss of Bond With Rebar Surface Spalling And Internal Cracking	Measure strain of concrete during SIT. Monitor strain gage on rebar and concrete.
Overstress	Applied Load Loss of Prestress Settlement	Severe Cracking High Rebar Loads Wire Relaxation	Measure strain of concrete during SIT at high stress locations. Monitor strain gage on rebar and concrete.
MIC	Moisture Environment Such As Below Grade Exterior Walls	Cracking And Loss Of Cement.	None Proposed.

Summary of Augmented Inspection

- ▶ Tendon load monitoring with fiber optic strain gages.
- ▶ Rebar strain gage monitoring.
- ▶ Concrete surface strain monitoring with Digital Image Correlation.
- ▶ Rebar corrosion protection monitoring with carbonation test.

Tendon Monitoring

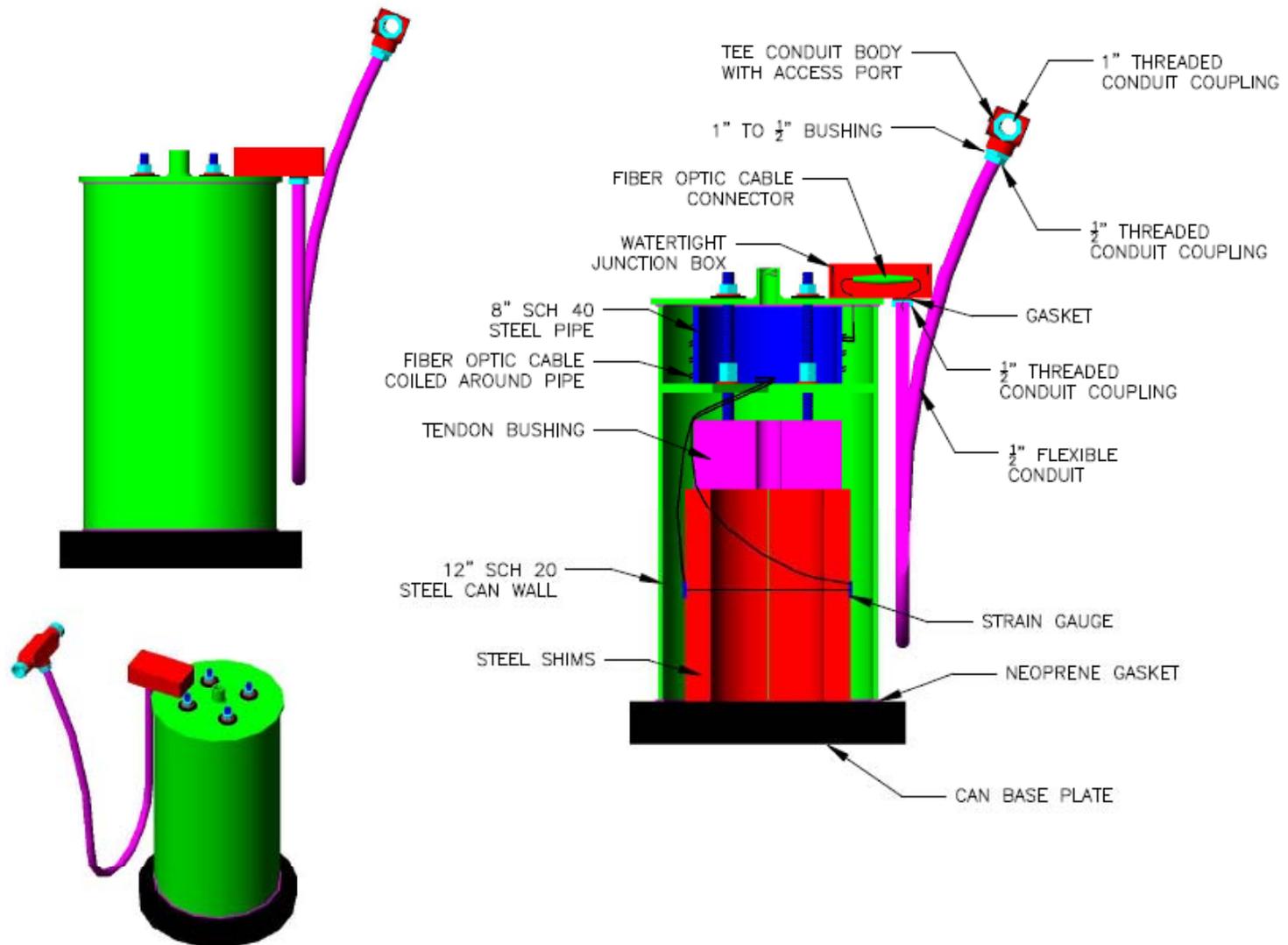
Fiber optic strain gages will be applied to the shims of 20 tendons.



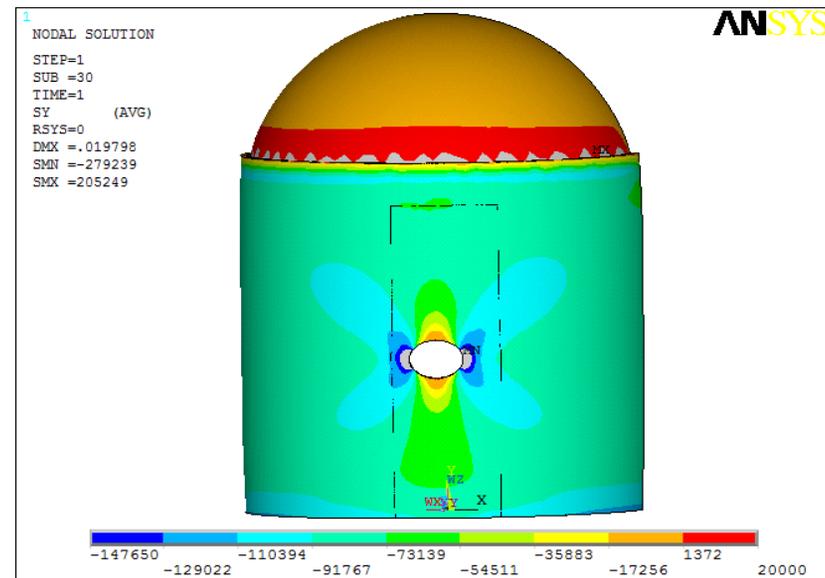
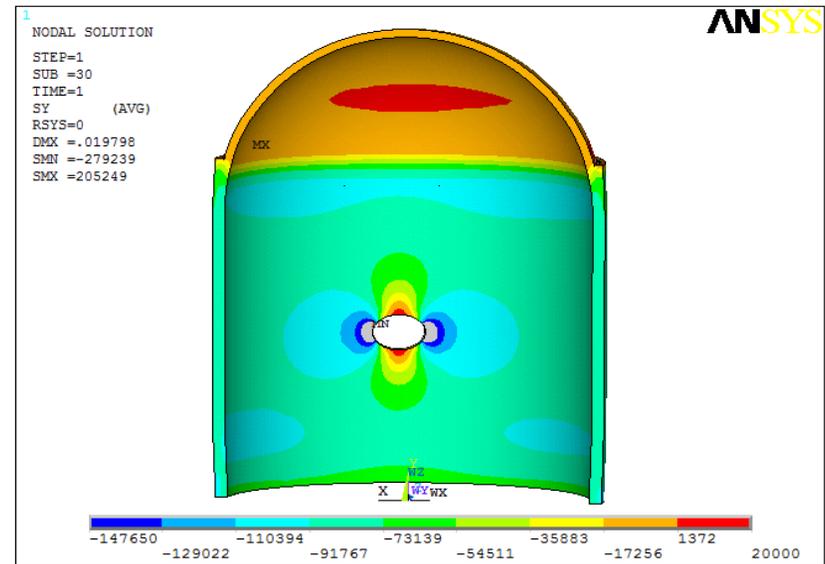
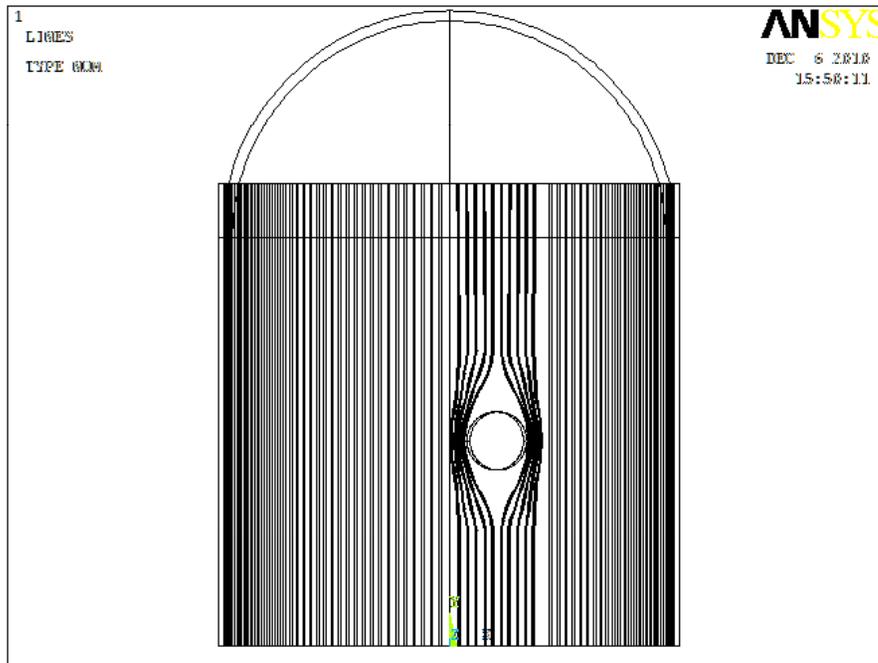
Post-Tensioning Tendon



Can Covering the Tendons



Tendon Monitoring Structural Behavior during Structural Integrity Test (SIT)



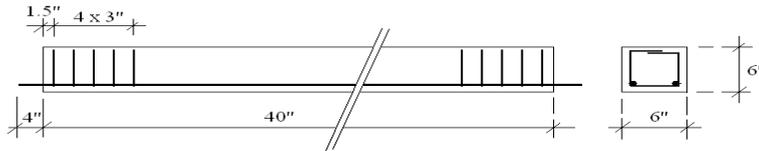
Rebar Strain Monitoring

- ▶ Select one currently exposed rebar and install fiber optic strain gage.
- ▶ Install concrete strain measuring fiber optic gage in close proximity to the rebar strain gage.
- ▶ Monitor both with the tendon monitoring system.

Digital Image Correlation (DIC)

- ▶ DIC is a non-destructive non-contact technique to measure changes in shape and strain on structure surface.
- ▶ DIC requires that a pattern be painted onto the surface.
- ▶ High-strain locations selected for DIC.
- ▶ Can be used to demonstrate that concrete shape is not changing due to swelling or other degradation and that strain is appropriate during SITs.

Digital Image Correlation (DIC) Lab Qualification



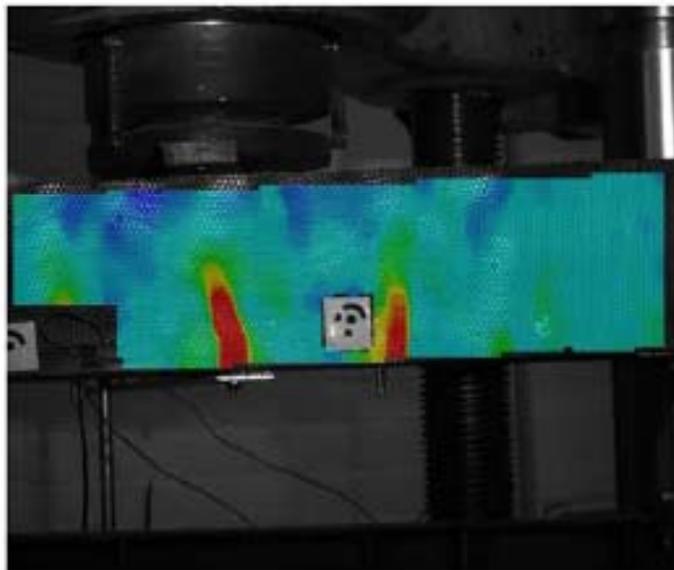
1. concrete compressive strength, f_c , is 4,000 psi
2. steel yield strength = 40,000 psi
3. main rebar are #4 (0.5" diameter)
4. stirrups are #1
5. main rebar center is 1.5" from near concrete surfaces



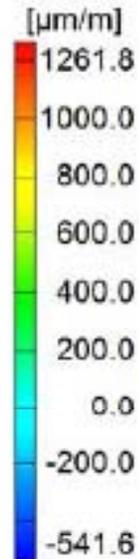
Concrete Beam

DIC Camera and Lights

Beam Second Loading Fri Oct 29



Epsilon X



6000 lb

Concrete Carbonation Test

- ▶ Carbonation is a chemical reaction of Portland cement with the atmosphere that causes reduction in concrete pH.
- ▶ Reduction in concrete pH makes rebar more susceptible to corrosion attack
- ▶ Tests are performed on external surface concrete with holes drilled into the concrete.
- ▶ If depth of carbonation penetration is less than rebar cover, corrosion protection is adequate.

Containment Inspection Guide

- ▶ An improved understanding of behavior and the results from the Ginna and NMP inspections will lead into the preparation of the Containment Inspection Guide.
- ▶ The guide will provide a methodology for baseline inspections and examinations and follow-up inspections for long term operation.