Time History Time Step Shift

Dryer Natural Frequencies

Non-Proprietary Version

Exelon Nuclear

[[

]]

Time History Time Step Shift

Participation Factors Non-Proprietary Version

Exelon Nuclear

[[

]]

Time History Time Step Shift

Modal Bandwidth Approach

Non-Proprietary Version

Nuclear

[[

]]

Time History Time Step Shift

Dryer Natural Frequencies Non-Proprietary Version

Exelon Nuclear

[[

]]

Time History Time Step Shift

Participation Factors Non-Proprietary Version

[[

]]

Time History Time Step Shift

QC1: Group 1 Components from Report

Exelon Nuclear

[[

]]

Time History Time Step Shift

Non-Proprietary Version

QC1: Group 1 Components from Report (cont.)

Exelon Nuclear

[[

]]

Time History Time Step Shift

QC1: Group 1 Components from Report (cont.)

Exelon Nuclear

[[

]]

Time History Time Step Shift: QC1

[[

]]

Effect on Design Margin

Additional Time History Cases: QC1

Exelon Nuclear

[[

]]

Effect on Design Margin

Additional Time History Cases: QC2

Non-Proprietary Version

Exelon Nuclear

[[

]]

Conclusions

- [[

  ]]
- All dryer natural frequencies are excited in the [[
  ]]
- [[
  ]]
- Maximum reduction in design margin of the five most limiting components, based on the additional runs, is [[ ]] (QC1) and [[ ]] (QC2)
- The original [[ ]] time history cases are sufficient to predict the dryer fatigue stresses

Exelon Nuclear

Strain Gage Sensitivity

Leslie Wellstein
General Electric

Item 10

Overall Dryer Strain Gage Uncertainty

- Perform an assessment of overall dryer strain gage uncertainty.
  - Perform a sensitivity study for the QC2 strain gage locations and orientations
  - Strain gages were installed within the following tolerances
    - Location: [[ ]]
    - Orientation: [[ ]]

Nuclear

The next 6 slides contain information that is proprietary to GE

Dryer Strain Gage Locations

Exelon Nuclear

[[

]]

Measured vs. Analytical Strains

[[

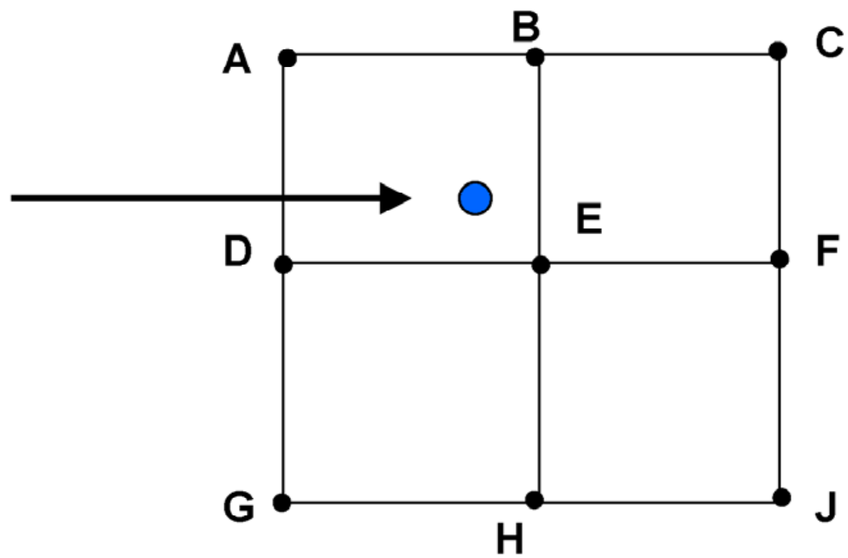
]]

Strain Gage Sensitivity Study

Exelon Nuclear

- Study examined three strain gages: S5, S7, and S9
- The strains in the FEM node closest to each strain gage (i.e., location E) and the eight nodes surrounding that node were evaluated
- Strain at each FEM node was examined at the correct horizontal or vertical orientation and then with a [[ ]] degree rotation
- Since the real strain gage location is known within [[ ]] inches, only four nodes around the actual strain gage are used to compare with the measured strains (locations A, B, D, and E in the diagram below)

Actual strain gage location in relation to FEM nodes



FEM mesh size ~ 3.0 inches

Non-Proprietary Version

S5 Sensitivity Results

Exelon Nuclear

[[

]]

S7 Sensitivity Results

Exelon Nuclear

[[

]]

S9 Sensitivity Results

[[

]]

Strain Gage Sensitivity

Conclusions

- Analytically determined strain is higher than measured strain at all three strain gage locations in the study, within the tolerance that the gages were applied to the QC2 dryer, by the following percentages
  - S5: [[ ]]
  - S7: [[ ]]
  - S9: [[ ]]

Structural Analysis Conclusions

Exelon Nuclear

- The three original time history analyses are adequate to represent the dryer fatigue stresses
- Minimum dryer design margins
  - QC1 = [[ ]]
  - QC2 = [[ ]]
- Analytically determined strains, within the tolerance of the applied gage location, bound the measured strain at all strain gage locations
- Both QC1 and QC2 replacement steam dryers are structurally adequate for long-term EPU operation

Exelon Nuclear

QC2 Dryer Design Margin

Guy DeBoo

Asset Management Engineer

Item 2

Exelon Nuclear

- Quantify the "end to end" uncertainty of the entire stress analysis and provide the technical basis.

QC2 Dryer Design Margin

Exelon Nuclear

- Dryer stress margins are determined using the stress analysis predicted strains with location and orientation uncertainties compared with the measured strains
- However, adjustments must be made to the measured strain before a comparison can be made

$$\text{Adjusted Strain Margin} = \frac{\text{Predicted Strain} - \text{Adjusted Measured Strain}}{\text{Adjusted Measured Strain}}$$

- Dryer design margins are determined by combining the margin between the predicted and measured strains with the margin between the predicted stress and the design endurance limits

QC2 Dryer Design Margins (cont.)

Exelon Nuclear

[[

]]

$$\text{Adjusted Strain Margin} = \frac{\text{Predicted Strain} - \text{Adjusted Measured Strain}}{\text{Adjusted Measured Strain}}$$

- Predicted component stress margins are obtained from QC2 EPU design margins with stresses extrapolated to 2957 MWt
- Stress margin to design endurance limit is the sum of the adjusted strain margin and the predicted stress margin for the dryer components

QC2 Dryer Design Stress Margin

Exelon Nuclear

- Dryer design stress margin based on strain gage measurements has been determined to be a minimum of [[ ]] when compared to the ASME code material endurance limit
- Dryer structural integrity is demonstrated for EPU operation

Exelon Nuclear

Startup Test Criteria for S-5, S-7, and S-9

Richard Wu
General Electric

Item 9

Exelon Nuclear

- Demonstrate that the startup test criteria on QC2 for strain gage locations S-5, S-7, and S-9 was met using calculated stress.

The next seven slides contain information that is proprietary to GE

Acceptance Criteria

[[

]]

Acceptance Criteria (cont.)

Exelon Nuclear

- [[

]]

Acceptance Criteria (cont.)

Exelon Nuclear

[[

]]

Acceptance Criteria
Strain Gages

Non-Proprietary Version

Nuclear

[[

]]

Criteria Calculation Methodology

Exelon Nuclear

- [[

]]

Conclusions

Exelon Nuclear

- All measured strains were below allowable limits at 2887 MWt
  - Margin compared with Level B criteria is [[ ]]
- Extrapolating to 2957 MWt maximum power, the margin to Level B criteria is [[ ]], based on extrapolation factor of [[ ]]

Exelon Nuclear

Basis and Justification for Continuous EPU Operations

Roman Gesior
Director – Asset Management

Technical Basis and Justification

Exelon Nuclear

- The acceptability for continuous operation of the Quad Cities units at EPU power levels is based on the following:
  - Startup testing results on both units
  - Conservative dryer design
    - FEA analysis
    - Strain gage predictions vs. measurements
  - Recent dryer performance
  - Periodic dryer inspection plan

Conservative Dryer Design

Exelon Nuclear

- ACM
  - Demonstrated to provide load predictions across the dryer surface with acceptable level of uncertainty
- FEM
  - Shown to accurately predict load frequencies when compared against hammer test results
- FEA
  - Conservatively utilized peak loads at +/- 10% frequency ranges using 2.5% intervals
  - Predicted strains on dryer components proven conservative when compared to measured values adjusted for uncertainty

Startup Testing

Exelon Nuclear

- Data collected during QC2 power ascent demonstrated structural integrity of the dryer design
  - Acceptance criteria for strain gages installed on the dryer met Level B design limits of [[ ]] at all strain gage locations
  - Level A fatigue stress limits of [[ ]] were never approached
- MSL strain gage data collected on QC1 demonstrated similarity in both the pressure excitation of the piping and response to the loading as QC2

Recent Dryer Performance

Exelon Nuclear

- Collection of strain gage data on the QC2 dryer during EPU operation following startup continued to demonstrate structural integrity of the dryer
- Site continues to monitor moisture carryover as an early indicator of potential structural degradation
- Moisture carryover on both units continues to remain below 0.1%

Periodic Dryer Inspection Plan

Exelon Nuclear

- Quad Cities will perform dryer inspections in accordance with GE SIL 644, Revision 1, and BWRVIP-139 supplemented with dryer specific inspections recommended by GE
- First dryer inspection is scheduled on QC2 in Spring 2006
- Inspections will focus on weld locations susceptible to fatigue from FIV
- Inspections will be performed on the interior and exterior of the dryer
- Frequency of inspections and recommended expansion criteria will ensure structural integrity of the dryer

Conclusion

Exelon Nuclear

- Sufficient technical basis exists to justify continued operation of QC1 and QC2 at full EPU power following installation of the replacement steam dryers

Exelon Nuclear

Summary and Conclusions

Patrick Simpson
Manager – Licensing

Evaluation of Data

Frequency Content

Exelon Nuclear

- Load ratios based on the integrals of the predicted and measured PSDs for each sensor were calculated
- Formulas to develop data were:

$$\text{PSDsumP} := \sum_{k=135}^{160} \text{PSD\_D1}_k$$

$$\text{PSDsumM} := \sum_{k=135}^{160} \text{PSD\_Dm}_k$$

$$\text{LoadRat} := \frac{\sqrt{\text{PSDsumP}}}{\sqrt{\text{PSDsumM}}}$$

Damping Values Non-Proprietary Version
Hammer Test

Exelon Nuclear

[[

]]

Damping Values Non-Proprietary Version
Hammer Test (cont.)

Exelon Nuclear

[[

]]

Damping Values Non-Proprietary Version
Hammer Test vs. Flow Induced Vibration

Exelon Nuclear

[[

]]

Damping Values

Exelon Nuclear

- [[

]]

Dryer Analysis Uncertainty Terms

RMS Pressure Band

Exelon Nuclear

Uncertainty Term	Absolute Effect %	Effect on Analysis
Strain Gage Measurement	5.03	+/- 5.03% based on assumption of linear model sensitivity
ACM Low Frequency Limitations		0.4% bias on RMS pressure
Pressure Sensor Measurement	3.9 Absolute 2.9 Relative	+/- 2.9%
Pressure Sensor Phenomenological	N/A	-3 to -8% bias on sensor reading
ACM Uncertainty		7.8% bias on RMS
Net Effect		5.2% net bias plus 5.81% (srss of measurement errors) Total=11.0%

Dryer Analysis Uncertainty Terms

Interval RMS Pressure

Exelon Nuclear

Uncertainty Term	Absolute Effect %	Effect on Analysis
Strain Gage Measurement	5.03	+/- 5.03% based on assumption of linear model sensitivity
ACM Low Frequency Limitations		0.4% bias on RMS pressure
Pressure Sensor Measurement	3.9 Absolute 2.9 Relative	+/- 2.9%
Pressure Sensor Phenomenological	N/A	-3 to -8% bias on sensor reading
ACM Uncertainty		13.1% bias on RMS
Net Effect		10.5% net bias plus 5.81% (srss of measurement errors) Total=16.3%