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Combination of Uncertainty Terms

Kevin Ramsden
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Summary of Uncertainty Terms

- MSL strain gage uncertainty is 5.03%
- Pressure instrument uncertainty is 2.9%
- Pressure instrument phenomenological bias is -3%
- ACM limitation (0 – 20 Hz loads) bias is +3%
- ACM bias is -0.5% using peak-to-peak data

Dryer Analysis Uncertainty Terms

Peak Pressure

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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		3% bias on peak-to-peak 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		0.5% bias on peak-to-peak
Net Effect		0.5% net bias plus 5.81% (srss of measurement errors) Total=6.3%

Uncertainty Terms

Conclusion

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- This review supports the conclusion that peak-based uncertainty is appropriate for application to this problem

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Additional ACM Blind Benchmark Results

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- Prove that the Modified 930 ACM will accurately predict loads for other cases/reactors.

Additional ACM Blind Benchmark

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- Continuum Dynamics, Inc. (CDI) performed blind benchmark tests at 790 megawatts-electric (MWe) and 930 MWe to demonstrate the accuracy of the ACM
- CDI made adjustments to the model following each benchmark
- To demonstrate that final adjustments to the Modified 930 MWe ACM were appropriate for use at all other power levels, CDI performed a third blind benchmark at 912 MWe

Dryer Loading Comparison
912 MWe (Using Range)

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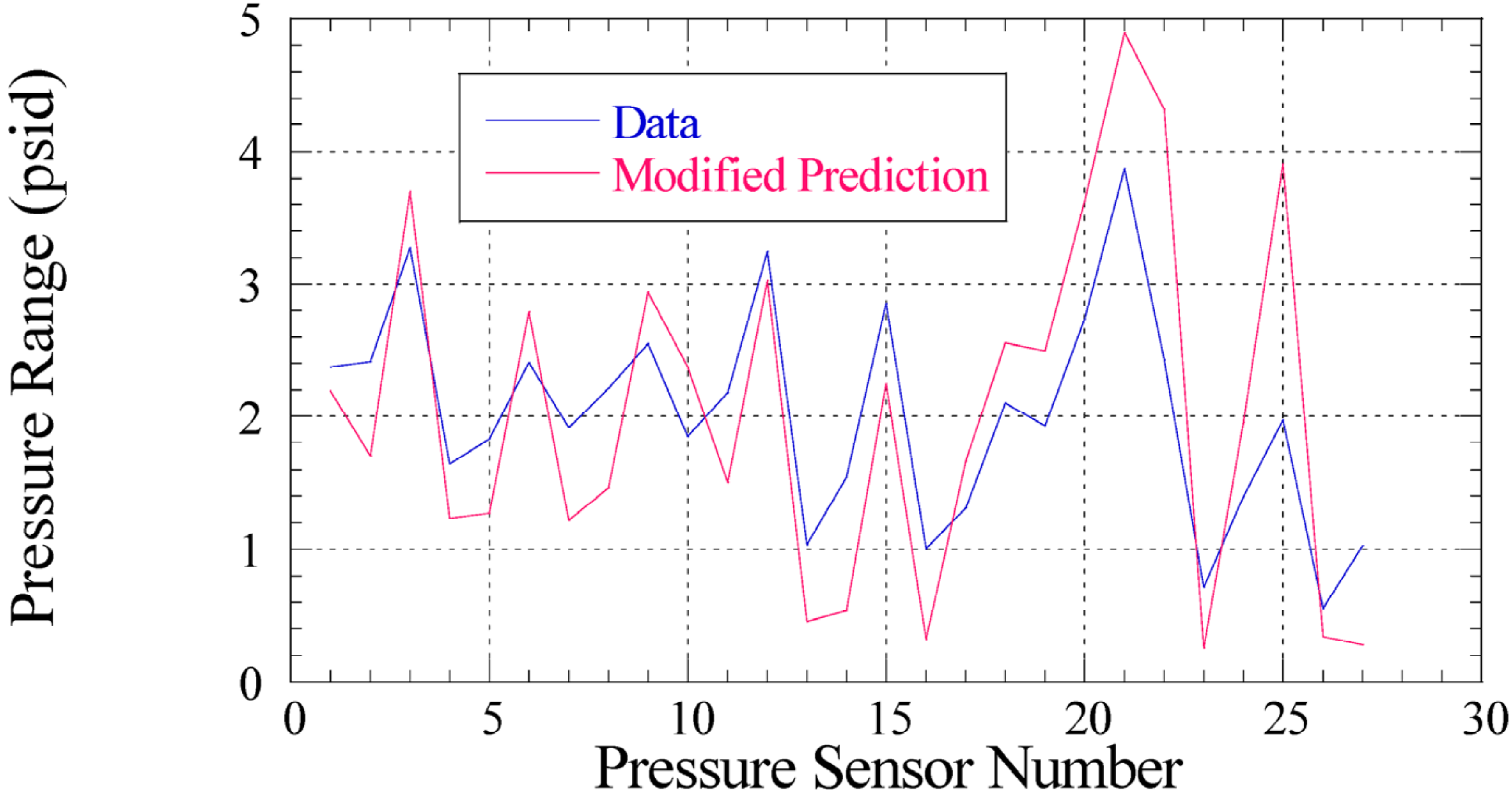
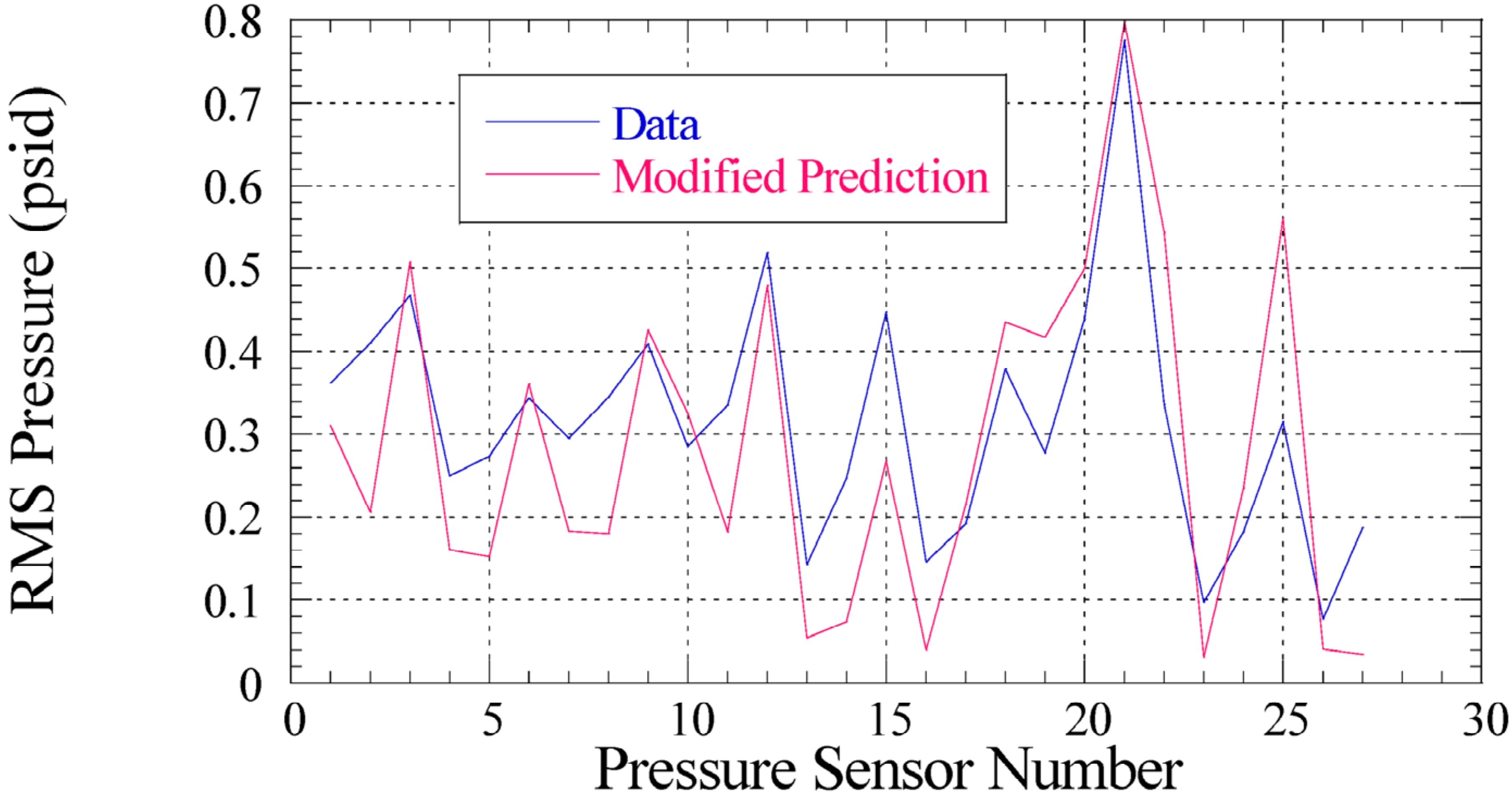


Dryer Loading Comparison

912 MWe (Using Root Mean Square (RMS))



Modified 930 ACM Uncertainty

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- The results of blind benchmark test results were evaluated to determine the range of uncertainty
- A ratio for each pressure transducer was generated by dividing predicted pressure at a dryer location by the measured pressure at the same location
- Ratios were generated using RMS predictions and range (peak-to-peak) predictions (a ratio > 1.0 indicates over prediction)
- A plot of ratios for each pressure sensor between all three benchmark tests was generated
- Trends indicate that the Modified 930 MWe ACM overpredicts dryer pressures at low power levels

Predicted vs. Measured Pressures

Comparison of Pressure Range Ratios

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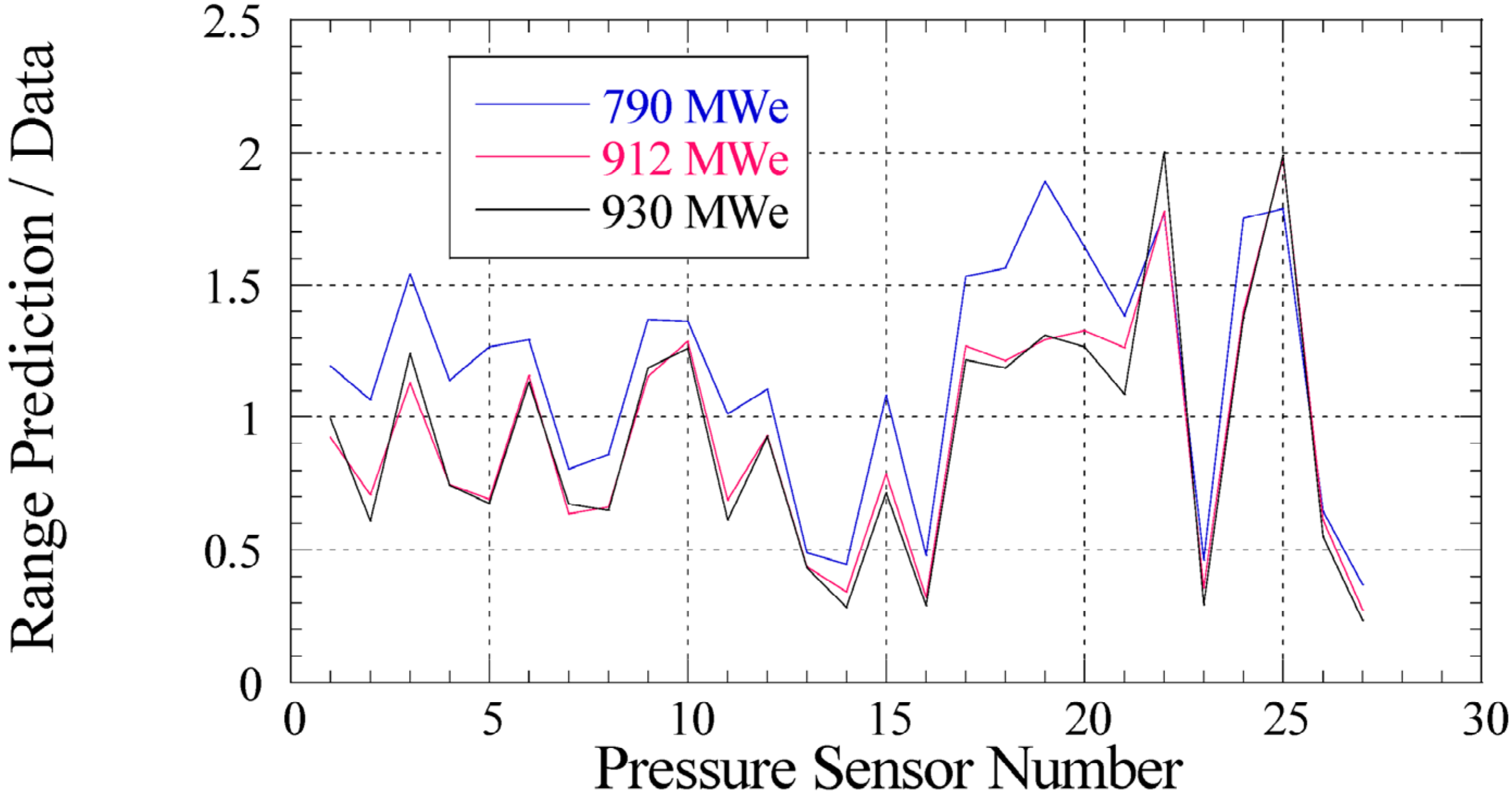

Predicted vs. Measured Pressures

Comparison of RMS Pressure Ratios

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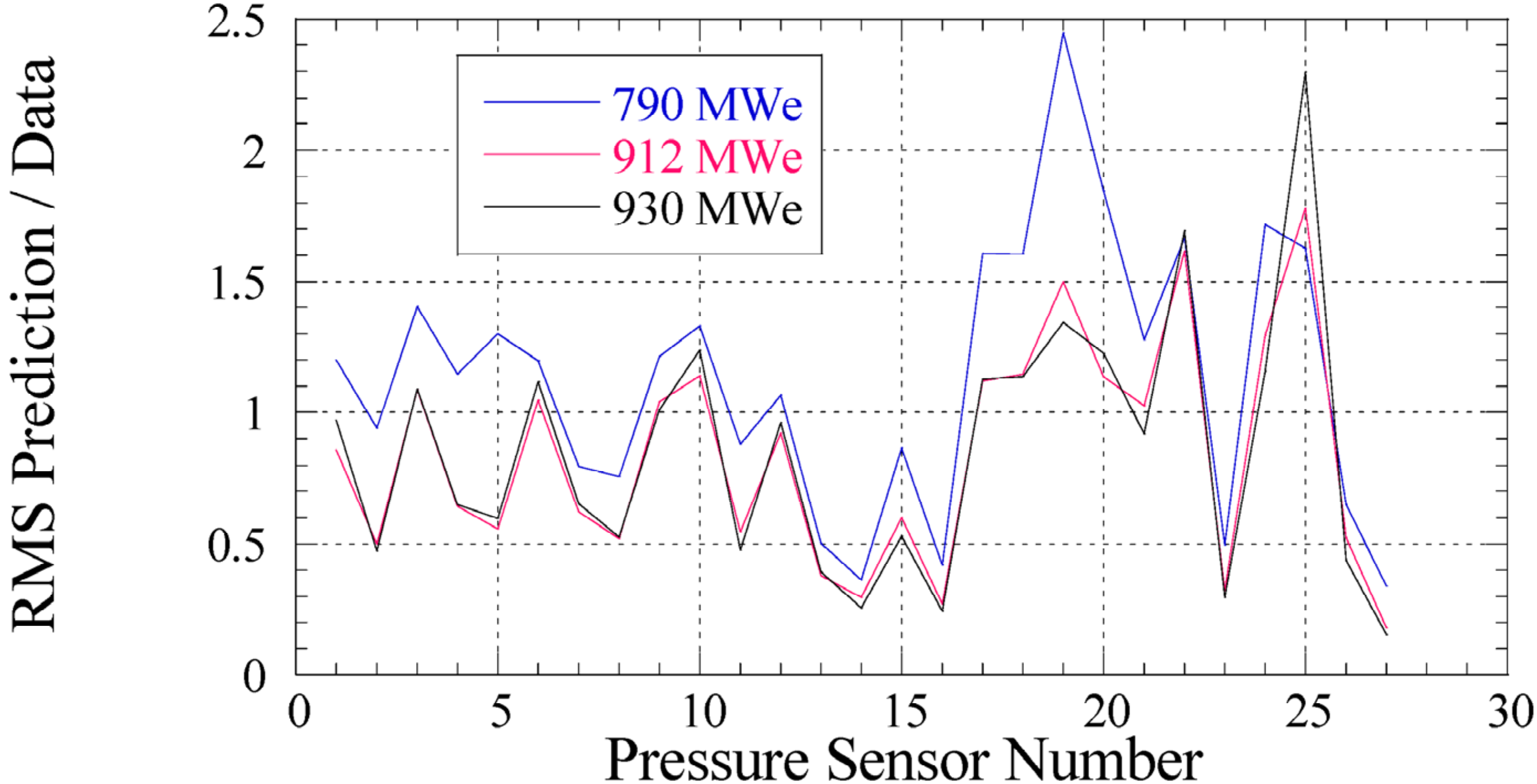

Cause of ACM Underpredictions

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- An analysis was performed by adjusting the ACM parameters that drive circuit prediction
  - Absorption at the steam froth interface beneath the dryer
  - Absorption at the steam water interface between the skirt & dome
  - Damping in the steam dome
  - Damping in the main steam line (MSL)
- Analysis determined that underpredictions are the result of a steam dome damping value that is too large
- EGC concluded that most of the damping of acoustic waves occurs inside the steam dryer where surface areas are large and the steam froth interface absorbs most of the radiated acoustic energy

Conclusions

- Evaluation of the 930 MWe ACM for the 912 MWe data (TC39) demonstrates that the model is adequate for generic steam dryer load prediction
  - The ACM becomes more conservative at lower steam flow rates

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Comparison of Hammer Test to FEA Predictions

Mike Neiheisel

LMS

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- The NRC has noticed that the two hammer test reports show differences in the resonance response between the two replacement steam dryers, and that the hammer test reports do not provide a comparison of the test results against the FEA predictions above 100 Hz.

Overview

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- Review of dryer #1 (QC2) versus dryer #2 (QC1)
- Review of dryer #1/dryer #2 versus finite element results
- Conclusions

The next six slides contain information that is proprietary to GE

Experimental and Analytical Data

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- Objective of experimental modal analysis: confirm that structural dynamics of actual dryers match those of dryer FEM
- Dryer #1 experimental modal analysis
  - Testing: April 2 - 7, 2005
  - Data processing: April 7 - May 14, 2005
- Dryer #2 experimental modal analysis
  - Testing: May 1 - 4, 2005
  - Data Processing: May 4 - June 28, 2005
- FEA
  - Up to [[ ]] April and May, 2005
  - Up to [[ ]] for outer hoods: September and October, 2005
  - Approach
    - Calculate modes up to [[ ]]
    - Use mode superposition in LMS Link to generate frequency response functions (FRFs) with same input points as test

Discussion of Correlation

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- At ambient conditions, frequency range of interest is [[ ]]
  - [[ ]] at ambient conditions is equivalent to [[ ]] at plant conditions (modulus decrease from ambient to plant conditions)
  - Expand to [[ ]] to approximately account for [[ ]] frequency variation of FEM to actual structure
- Correlation on FRF basis due to high number of modes
  - Impractical to correlate specific mode shapes of outer hood in this frequency range
- Use summation FRFs over hood to get component level view of outer hood

Dryer #1 vs. Dryer #2

90° Outer Hood Non- Proprietary Version

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- [[

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Dryer #1 vs. Dryer #2

270° Outer Hood Non-Proprietary Version

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Test vs. FE

90° Outer Hood Non-Proprietary Version

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Test vs. FE

270° Outer Hood Non-Proprietary Version

Exelon Nuclear

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Conclusions Non-Proprietary Version

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- The outer hoods of dryer #1 and dryer #2 are structurally similar
  - The amplitude of the FRFs, the frequency peaks that indicate resonances and the trends of the FRFs are very similar in the frequency range of interest
- The FEM adequately represents the outer hoods of the actual dryer
  - The FRF frequency content and amplitudes are acceptable in the frequency range of interest
- The frequency variation performed during the FE stress analysis [[ ]] cover the whole frequency range of interest with an overprediction to ensure the results are conservative

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Steam Dryer Load Extrapolation

Mike Neiheisel

LMS

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- The methodology used to extrapolate loads to 2957 megawatts-thermal (MWt) utilized a power factor of four. Evaluate the conservatism of this approach when compared to pressure transducer plots from startup data.

Overview

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- Brief discussion of experimental data
- Discussion of approach
- Brief review of experimental data
- Conclusions

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Data Used for Extrapolation

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Time Domain Data

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- Sampling rate for all dryer data: [[ ]] (all dryer sensors)
- Time record length: 103 seconds to 208 seconds
  - Power ascension: 186 to 208 seconds
  - Summer: 103 to 187 seconds (only 1 set was 103 seconds; remainder were 153 to 187 seconds)

Approach

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- Scaled strain/stress focuses on use of strain results
- Strain is indicative of dryer structural response
- Used time domain strain range and peak strain amplitude
  - Used thermal power levels above 2480 MWt
- Performed power law curve-fitting on range and peak values
- Developed scaling factors based on [[ ]] to extrapolate from 2885 MWt to 2957 MWt

Time Domain Strain Data

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Time Domain Strain Data (cont.)

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Time Domain Strain Data (cont.)

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Frequency Domain Results

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Hood/Upper Component Strain Gages

150 to 160 Hz Section Non-Proprietary Version

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Hood/Upper Component Strain Gages

150 to 160 Hz Section

[[

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Conclusions Non-Proprietary Version

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- Hood and dryer components: [[ ]]
  - Corresponds to a [[ ]]
  - Result of [[ ]] section for strain gages S5, S7, and S9
  - Maximum power exponent for 2480 MWt to 2900 MWt strain range and peak strain was [[ ]]
- Skirt components: [[ ]]
  - Corresponds to a [[ ]]
  - Maximum power exponent for 2480 MWt to 2900 MWt strain range and peak strain was [[ ]] (but poor coefficient of determination)
  - Based on strain gages S1 and S8

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FEA Frequency Analysis/ Component Stress Margins

Leslie Wellstein

General Electric

Structural Analysis Agenda

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- Brief review of original analysis assumptions
- Review dryer design margins
  - Assumptions
  - Margins based on [[ ]] and nominal cases
- Address time history [[ ]] time step shift (use QC1 Group 1 components as an example)
  - Margins based on all time history runs
- Summary of strain gage location and orientation sensitivity study
- Conclusions

Item 2

Overall Stress Analysis Uncertainty

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- Quantify the "end to end" uncertainty of the entire stress analysis and provide the technical basis.
  - Modify the stress margin tables to show actual margins allowed by Code, removing all available conservatism

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Original Time History Analysis

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- Three time history analyses are run for each load case (QC1 and QC2): nominal, [[ ]] frequency shifts
- [[ ]] damping on the dryer, [[ ]] damping on the skirt and vane banks
- Load extrapolation to EPU used [[ ]]
- Fatigue analysis performed using weld factors applied to time history analysis results
- Disposition of high stress locations using 1) local solid FEMs with forces extracted from the full shell model, and 2) increased damping for skirt and vane banks

Current Design Margins

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Assumptions/Reduced Conservatisms

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- Used the [[ ]] pounds force per square inch (psi) fatigue limit only on outer components (used [[ ]] psi on all other components)
- Used revised FEM (trough and closure plate changes reported previously) for both QC1 and QC2 analyses
- Removed any conservative weld factors (for example: a fillet weld factor was conservatively applied at some full penetration weld locations)
- Used new load extrapolation scaling factors ([[ ]] to scale from 2887 MWt to 2957 MWt)
- Used [[ ]] damping results for the vane banks per the design specification (conservatively used [[ ]] in results reported previously)

EPU Design Margins

QC1

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EPU Design Margins

QC2

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Revised EPU Design Margins

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- QC1 EPU minimum design margin is [[ ]]
- QC2 EPU minimum design margin is [[ ]]

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Time History Analysis Time Step

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- Explain the efficacy of using [[ ]] time step shifts in the frequency spectrum used for stress analysis and demonstrate that significant frequency peaks contributing to the dryer load were not missed. Demonstrate the accuracy of the FEA.

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