ATTACHMENT 2

GE-ENG-DRY-172

NRC Presentation, "Quad Cities Replacement Steam Dryer Meeting", November 8-9, 2005

Non-Proprietary Version

IMPORTANT NOTICE

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Quad Cities Replacement Steam Dryer Meeting

November 8 - 9, 2005

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Introduction

Thomas Roddey
Licensing Engineer

Agenda

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- Introduction
- Opening Remarks
- Open Issues
- Basis and Justification for Continuous Extended Power Uprate (EPU) Operations
- Summary and Conclusions

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Opening Remarks

Roman Gesior

Director – Asset Management

Meeting Objectives

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- Provide answers to open issues from the last technical meeting
- Review the results of additional work performed in the following areas:
  - Acoustic circuit model (ACM) uncertainty
  - Finite element model (FEM) and finite element analysis (FEA) accuracy
  - Quantifying overall dryer design margin

ACM

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- Discuss ability of the ACM to predict loads at low frequency range and demonstrate the structural impact on the dryer design
- Review the methodology used to determine the uncertainties associated with the ACM analysis
- Demonstrate that the overall uncertainty associated with the ACM are reasonable
- Demonstrate the reliability of the ACM to predict dryer loads during our discussion of additional blind benchmark testing

FEM and FEA

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- Demonstrate the accuracy of the accuracy of the FEM by comparing the results of hammer testing against FE predictions
- Demonstrate the conservatisms used in developing scaling factors used to extrapolate loads to full extended power uprate (EPU) operation
- Demonstrate that the approach used in the dynamic analysis captures all significant contributing frequency peaks

Overall Dryer Design Margin

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- Discuss strain sensitivity to orientation and location changes in strain gage location
- Discuss stress margins on individual components
- Demonstrate design margin by reviewing the startup test criteria for several strain gage locations
- Review the analysis of overall "end to end" dryer design margin
- Provide basis and justification for continuous EPU operation

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Open Issues

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Open Issues

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1. The ACM underpredicts some locations on the Quad Cities Unit 2 (QC2) dryer specifically for components sensitive to 157 hertz (Hz). Explain why the ACM underpredicts for these specific locations and what impact it has on the final stress uncertainty.
2. Quantify the "end to end" uncertainty of the entire stress analysis and provide the technical basis.
3. Demonstrate that the modified 930 MWe ACM will accurately predict loads for other cases/reactors.
4. Explain the efficacy of using +/- 10% 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.
5. The ACM omits low frequency loads. Evaluate the structural impact on the dryers.

Open Issues (cont.)

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6. 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.
7. 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.
8. Discuss the comparison of MSL strain gage data collected on both units is an appropriate basis for continued operation of QC1.
9. Demonstrate that the startup test criteria on QC2 for strain gage locations S-5, S-7, and S-9 was met using updated FEM and loads.
10. Perform an assessment of overall dryer strain gage sensitivity.

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Overall ACM Uncertainty

Guy DeBoo
Asset Management Engineer

Kevin Ramsden
Senior Staff Engineer

Overall ACM Uncertainty

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- Low Frequency Load
- Assessment of ACM Uncertainty
- Combination of Uncertainty Terms
- Additional ACM Benchmark Results

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Low Frequency Loads

Guy DeBoo
Asset Management Engineer

Item 5

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- The ACM omits low frequency loads. Evaluate the structural impact on the dryers.

ACM Load Prediction
< 18 Hz

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- ACM underprediction is a function of strain gage spacing on MSLs
- Loss of signal discrimination will occur if both strain gage locations are within the quarter wave spans
- Strain gages installed at 651' and 621' elevations in the drywell
- Strain gage spacing of 30' and acoustic speed of 1600 feet per second (fps) yields a frequency of 13.3 Hz
- ACM predicted pressures compared to measured suggests a loss of low frequency signal prediction below 18 Hz

ACM Load Prediction
Effect of Low Frequency Omission

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- Low frequency signal content was filtered from measured data on QC2 dryer
  - Four pressure sensor locations nearest MSL nozzles were selected (P-3, P-12, P-20, and P-21)
  - Digital filter was set to remove frequency components from 0-20 Hz
- Loads omitted by the ACM model in the 0-20 Hz range are negligible
  - 3% uncertainty bias conservatively bounds the loss of 0-20 Hz loading components

0-20 Hz Components
Contribution to Total Load

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Structural Impact on Dryer

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- The dryer [[ ]] is the only component with modal frequencies in the [[ ]] range
- Some modal response was observed on the inner hoods at [[ ]]
- Primary modal response at the inner hoods occurs at [[ ]]
- Fundamental mode of the outer hood is [[ ]]
- Strain levels measured on the QC2 dryer skirt are an order of magnitude lower than the strain levels from the FEA

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The next four slides contain information that is proprietary to General Electric (GE)

Fundamental Modal Response

Dryer Skirt

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Dryer Modal Response

Inner Hoods and Skirt

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Dryer Modal Response
Inner Hoods

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Dryer Modal Response
Outer Hoods

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Strain Comparison

Skirt Location S-1 Non-Proprietary Version

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Strain Comparison

Skirt Location S-8 Non- Proprietary Version

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Conclusion

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- The loads from the ACM applied to the finite element model (FEM) are conservative for the skirt, and any underprediction of the load from 0-20 Hz is of no consequence on the skirt

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Assessment of ACM Uncertainty

Kevin Ramsden
Senior Staff Engineer

Item 1

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- The ACM underpredicts some locations on the Quad Cities Unit 2 (QC2) dryer specifically for components sensitive to 157 hertz (Hz). Explain why the ACM underpredicts for these specific locations and what impact it has on the final stress uncertainty.

Introduction

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- The Modified 930 MWe ACM takes inputs from the strain gages mounted to the MSL piping, and provides a detailed pressure time history of the volume of the reactor steam dome and the surfaces of the steam dryer
- The overall uncertainty of the ACM load history is a function of the following factors:
  - Accuracy of the MSL strain gages
  - Accuracy of the QC2 pressure transducers attached to the dryer
  - Accuracy of the ACM
  - Limitations of the ACM (underpredicts loads <18 Hz)

MSL Strain Gage Accuracy

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- MSL pipe strain gage measurement uncertainty is composed of two major components
  - Instrumentation, cabling, and data acquisition response
  - Conversion of hoop strain to pressure (wall thickness of pipe)
- Ultrasonic wall thickness measurements were made on the pipe wall at the strain gage locations to minimize uncertainty
  - A value of +/-5.03% was determined to be the accuracy of the strain gage measurements

Steam Dryer Pressure Uncertainty

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- Uncertainty in dryer pressure measurements consists of two components
  - Instrument accuracy and calibration results
  - Phenomenological effects
- Instrument accuracy of pressure transducers, based on vendor supplied data and calibration results, was +/-2.9% relative, and 3.9% absolute
- Phenomenological considerations yield > +3% conservative bias

ACM Uncertainty

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- Validation of the Modified 930 MWe ACM was made by comparing the predicted pressure values against actual measurements at 22 dryer pressure sensor locations
- A statistical analysis was performed comparing:
  - Peak pressures (maximum and minimum)
  - Standard deviation (RMS pressure)
- A spectral analysis was performed using complex fast Fourier transforms (FFTs) to characterize frequency content and power spectral density (PSD) of the measured data

ACM Uncertainty

Uncertainty Value

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- Uncertainty using RMS pressures would be appropriate if energy storage and buildup is observed in the structural model, as evidenced by peak stresses building and reaching a maximum at the end of the analysis interval
- Uncertainty using peak-to-peak pressures would be appropriate if the structure is driven by load, but not in a resonant response mode
- Predicted strain time histories for five dryer strain gage locations were reviewed to determine if the peak predicted strains were distributed randomly in the analysis interval, or if there is evidence of buildup effects in the FEM

Strain Time Histories

Strain Gage S-1 (Skirt)

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Strain Time Histories

Strain Gage S-5 (Hood)

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Strain Time Histories

Strain Gage S-7 (Hood)

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Strain Time Histories

Strain Gage S-8 (Skirt)

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Strain Time Histories

Strain Gage S-9 (Hood)

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Summary of Strain Time Histories

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- With the exception of strain gage S-8, the strain time histories demonstrate that there is no evidence of any energy buildup effects
- The oscillations at S-8 are periodic, and the peaks grow throughout the interval; this location appears to be exhibiting energy storage and response buildup
- The strains at S-8 (skirt) are much larger than at the other locations, and the applied loads for this case are known to be conservative by a factor of at least two in RMS and peak pressure
- Peaks are distributed over the interval, and show no tendency to grow with time for strain gages S1, S5, S7, and S9

Conclusion

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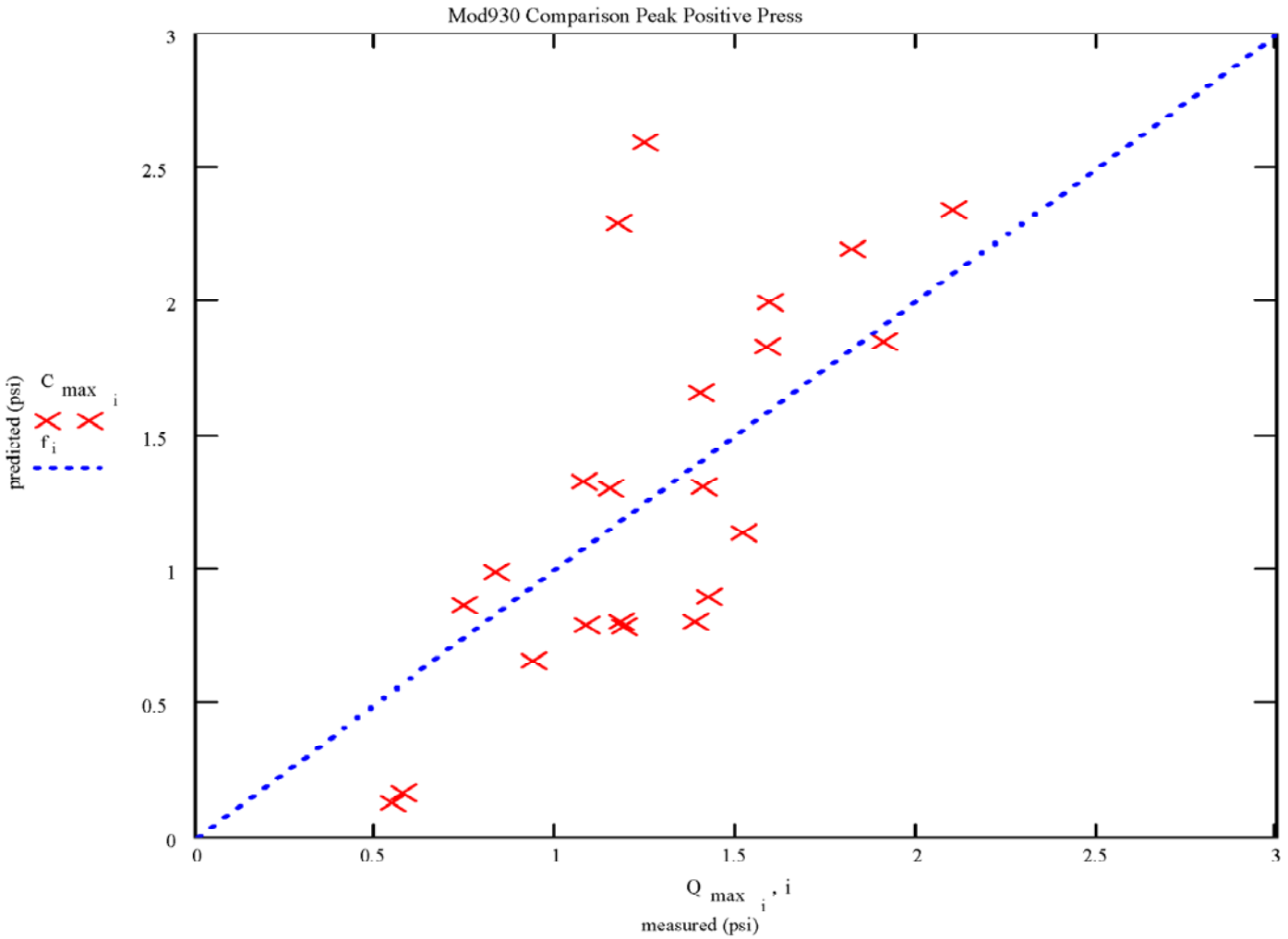
- Except for S-8, the strain time history behavior observed for all points support the hypothesis that the FEM does not show buildup and energy storage
- For the S-8 location, the applied loads are known to be overpredicted by a large margin
- Therefore, this review supports the conclusion that peak-based uncertainty is appropriate for application to this problem

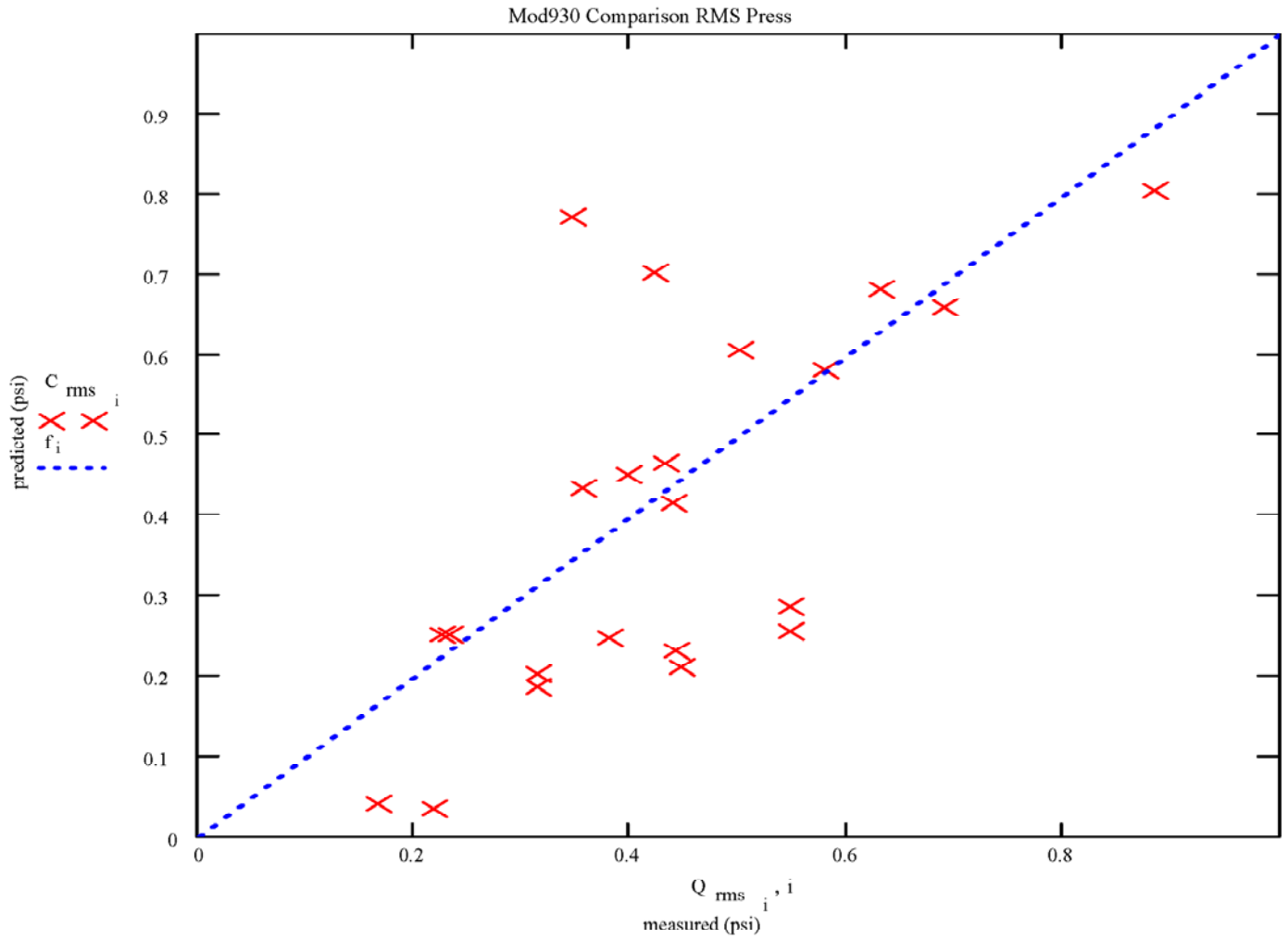
ACM Uncertainty

Peak Positive Pressure Comparison



Peak Positive Pressure Comparison

ACM Uncertainty
RMS Comparison



RMS Comparison

Development of Bias Uncertainty

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	μ(Predicted- Measured)	μMeasured	Bias % of measured
RMS	-0.034	0.432	-7.8
Peak Pos.	0.04	1.324	3.2
Peak Neg.	0.036	-1.319	-2.7

Based on the above results, one would apply a bias correction of 7.8% to the RMS values, and a –0.5% bias correction to the peak-to-peak pressures.

Summary of Statistical Results

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- Modified 930 MWe ACM predicts the highest RMS pressures well, with peak positive pressures and peak negative pressures showing a similar trend
- The ACM generally overpredicts the largest peak pressures while underpredicting lower pressure points

Evaluation of Data

Frequency Content: 135 – 160 Hz RMS

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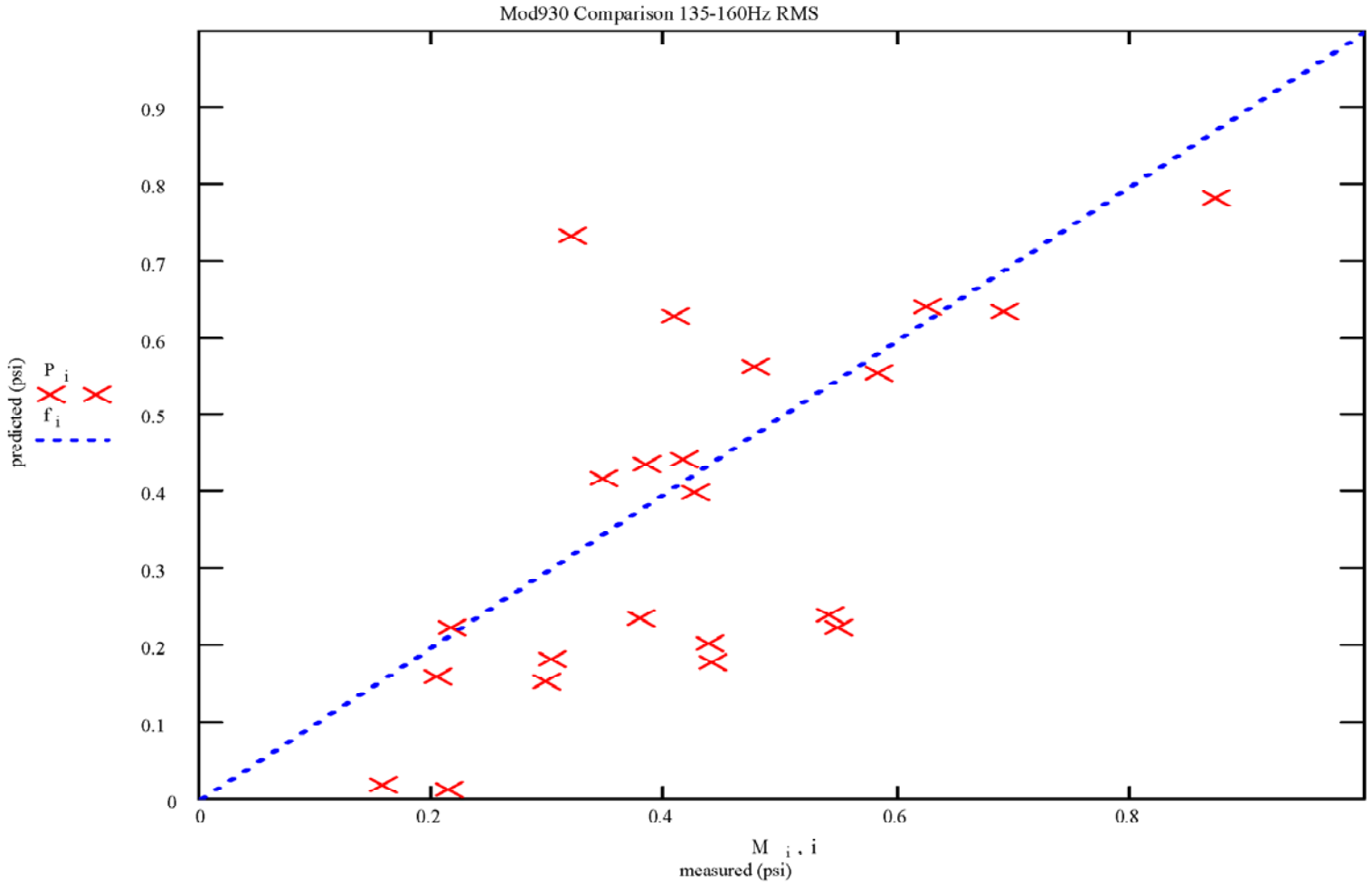

Evaluation of Data

135 - 160 Hz Interval Statistics

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	μ(Predicted- Measured)	μMeasured	Bias % of measured
RMS 135-160 Hz	-0.055	0.42	-13.1
Global RMS	-0.034	0.432	-7.8

- The frequency range of interest accounts for most of the steam dryer loading

Summary of Uncertainty Terms

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- MSL strain gage uncertainty is 5.03%
- Pressure instrument uncertainty is 2.9%
- Pressure instrument phenomenological bias is -3% to -8%
- ACM limitation (0 – 20 Hz loads) bias is +3% peak-to-peak, and 0.4% RMS
- ACM bias is:
  - 7.8% using RMS data
  - -0.5% using peak-to-peak data
  - 13.1% using RMS 135 - 160 Hz

ACM Uncertainty
Conclusions

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- Modified 930 MWe ACM tends to overpredict the largest pressures while underpredicting lower measured pressures
- Based on the distribution of over- and underpredictions, a net bias-based uncertainty is -0.5% for peak-to-peak