ENCLOSURE 2

Attachment 4

Exelon Report Number AM-2005-006, "Comparison of Acoustic Circuit Dryer Loads for Missing MS Line Strain Gages to Acoustic Circuit Dryer Loads with All MS Line Strain Gages," Revision 0, dated July 19, 2005

Comparison of Acoustic Circuit Dryer Loads for Missing MS Line Strain Gages to Acoustic Circuit Dryer Loads with All MS Line Strain Gages

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Abstract

This report documents the comparison of the CDI acoustic circuit steam dryer load predictions using MS line pressure inputs from four hoop direction strain gages at two locations on each steam line to predictions using MS line pressure inputs missing some of the strain gage measurements. This comparison is intended to support the development of engineering judgements regarding the relative acoustic pressures of the QC1 and QC2 steam paths and the resultant loads on the steam dryers at EPU conditions.

1. Introduction

This report documents the comparisons of the steam dryer pressure loads predicted by the CDI acoustic circuit model for MS line pressures that are changed because some of the strain gages used to determine the steam line dynamic pressures failed. Main steam line dynamic pressures at two separate locations on each steam line are required as input to the acoustic circuit model for it to calculate the acoustic pressures acting on the steam dryer. For this purpose, four hoop direction strain gages were mounted at 90° intervals about the circumference of the main steam piping and used to measure the dynamic pressures in the main steam line at that specific location. The location of the strain gages as mounted on the steam lines can be seen in Figure 1.

During the power ascension testing subsequent to replacement of the steam dryers on both units, main steam line strain gage measurements were collected on both units. All of the strain gage data was collected on Quad Cities Unit 2 at 2884 MWt for use in developing the acoustic pressure loads on the dryer. During the start-up test for Quad Cities Unit 1, some of the steam line strain gages failed prior to reaching this power level and collecting strain measurements on all four strain gages at each piping location. The effect of these strain gage failures is to cause an overprediction of the dynamic pressures at these locations in the main steam lines. The higher magnitude pressures and additional frequency content is then transformed into higher predicted loads on the dryer by the acoustic circuit model.

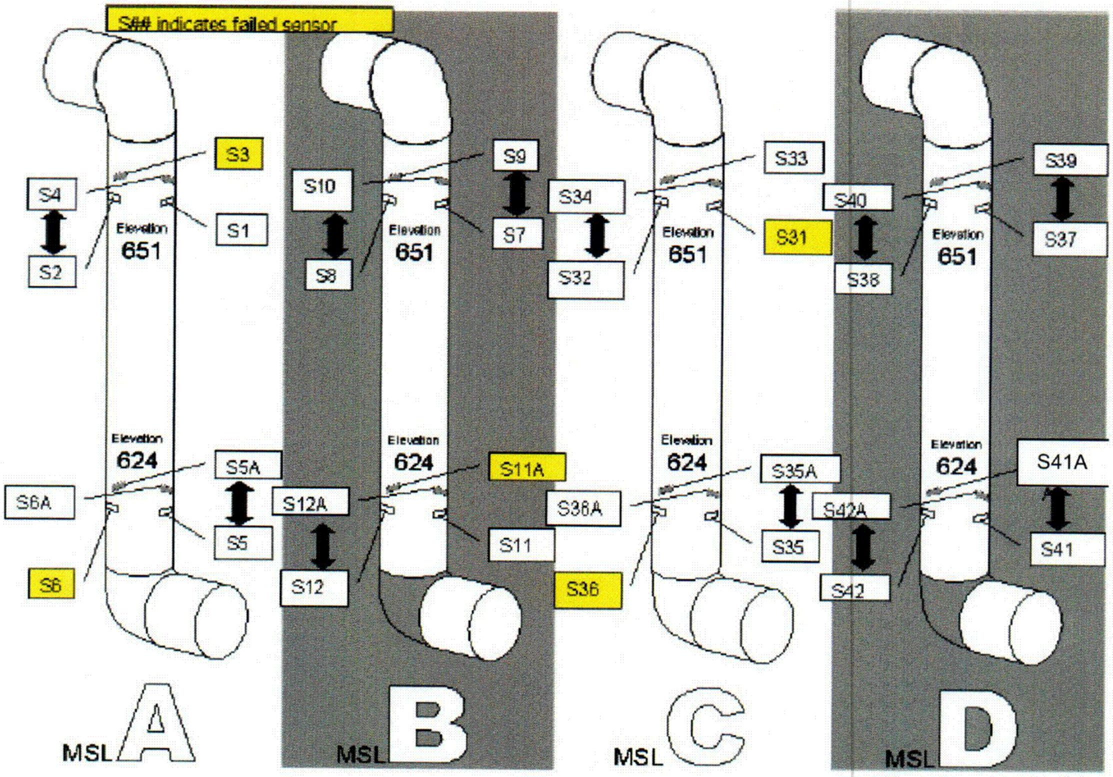

Figure 1: QC1 Main Steam Line Strain Gage Locations and Identification of the Missing Strain Gages

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2. Description of Test Data

The power ascension testing was performed at the highest thermal power levels achievable at the time of the testing. The plant electrical output tended to become limiting prior to reaching maximum licensed thermal power. The test conditions being compared in this report are:

1) QC1 Test Condition 15A, performed at 2887 MWt on 6/5/2005.
2) QC2 Test Condition 41, performed at 2884 MWt on 5/23/2005.

To determine the dynamic pressures, the four strain gage measurements at each location were averaged in the time domain to provide the best measure of the breathing mode of the pipe. This combined hoop strain, when converted into pressure, provides the best measure of the dynamic pressure at this location. The strain gages that were 180° apart from each other were connected in half-bridge configurations and the two half-bridge measurements at each location were then averaged.

The main steam line strain gage measurements for these test conditions are summarized in the Table 1 below. This table provides the measured peak to peak strains and RMS strains for the working strain gage pairs on Unit 1 and compares these values to the same strain gage pairs on Unit 2. For the steam line locations on Unit 1 that had all four strain gages working, the combined measurement is compared to the combined measurement from Unit 2. The Quad Cities Unit 1 strain gages that had failed during the start-up are identified on Figure 1.

	RMS Values ($\mu\varepsilon$)			Peak to Peak Values ($\mu\varepsilon$)		
Description	**U1 TC15a 2887 MWt**	**U2 2884 MWt SG Pair**	**U2 2884 MWt All SGs**	**U1 TC15a 2887 MWt**	**U2 2884 MWt SG Pair**	**U2 2884 MWt All SGs**
MSL A 651 (S2/S4)	0.459	0.422	0.300	4.275	3.334	2.401
MSL B 651 (All)	0.216		0.297	1.849		2.453
MSL C 651 (S32/S34)	1.110	0.593	0.333	9.629	4.462	2.529
MSL D 651 (All)	0.237		0.344	2.166		2.919
MSL A 624 (S5/S5A)	0.275	0.914	0.427	2.358	6.242	3.346
MSL B 624 (S12/S12A)	0.353	0.337	0.251	3.138	3.186	2.274
MSL C 624 (S35/S35A)	0.371	0.272	0.221	3.011	2.236	1.958
MSL D 624 (All)	0.325		0.380	2.529		2.735

Table 1: QC1 and QC2 Main Steam Line Strain Gage Measurements

The strain measurement comparisons, i.e. RMS and peak to peak values at each steam line location, seen in Table 1, show the strain measurements to be very similar for all 651 steam line locations except the C steam line. The most significant difference in strain measurements occurs at this location. The Quad Cities Unit 1 strains (at MSL C 651 (S32/S34)), are 1.87 and 2.16 times greater than the Quad Cities 2 single pair RMS and Peak to Peak strains, respectively. The Table 1 strain measurement comparisons show the 624 steam line strain measurements to be very similar for all locations except the A steam line where the Quad Cities Unit 2 RMS and Peak to Peak strains are greater than Quad Cities Unit 1. For the Quad Cities Unit 2, strain gage data, the net strain results obtained when combining all the strain gages at a location is always less than the individual strain gage pair at that location. For example, the Quad Cities Unit 2 RMS and Peak to Peak strains for MSL C 651 (S32/S34) strain gage pair are 0.593 and 4.462 $\mu\varepsilon$ respectively, and RMS and Peak to Peak strains for all the strain gages at this location are 0.333 and 2.529 $\mu\varepsilon$ respectively. Comparing these strains, the S32/S34 pair strains are 1.78 and 1.76 times greater than the combined strain from all the strain gages at this location for the RMS and Peak to Peak strains, respectively.

3. Acoustic Circuit Model Calculations

The CDI acoustic circuit model was used to predict the steam dryer acoustic pressure loads using the Quad Cities Unit 2 main steam line pressures based on all the strain gage data. To understand the effect of the missing strain gage data, the acoustic circuit model was also used to predict the pressure loads on the steam dryer using the Quad Cities 2 main steam line pressures based on just the strain gage pairs that were functional on Unit1. For this second acoustic circuit model calculation, the strain gages that were used to define the main steam line dynamic pressure are listed in Table 2.

MS Line Location	Strain Gage Pairs
MSL A 651	S2/S4
MSL B 651	S7/S9 & S8/S10
MSL C 651	S32/S34
MSL D 651	S37/S39 & S38/S40
MSL A 624	S5/S5A
MSL B 624	S12/S12A
MSL C 624	S35/S35A
MSL D 624	S41/S41A & S42/S42A

Table 2: Quad Cities 2 Strain Gage Pairs Used to Define the Acoustic Circuit Model Pressure Inputs for the Missing Strain Gage Model

The predictions from these two analyses are then compared to determine impact caused by the missing strain gage data on the dryer acoustic pressure loads.

4. Acoustic Circuit Model Results

The acoustic circuit model pressure predictions for the steam line pressures using all the strain gage data and for the missing strain gage data have been summarized in Reference 1. For this comparison, the predicted dryer pressures opposite the main steam line nozzles are being compared as these are the highest pressures on the dryer and best represent the effect of the line acoustic pressures on the dryer loading. Table 3 provides a summary of the RMS pressures on the dryer for the two acoustic circuit models and also presents the pressures measured at these locations during the start-up test, (TC 41).

Dryer Location	QC2 All Data (psid)	QC2 Missing Data (psid)	QC2 Measured Data (psid)
MSL A – P3	0.682	0.610	0.626
MSL B – P12	0.659	0.657	0.684
MSL C – P20	0.605	1.085	0.493
MSL D – P21	0.804	0.824	0.878

Table 3: Predicted RMS Pressures from Acoustic Circuit Models

The RMS pressure opposite MSL C is significantly greater for the Missing Data case than the All Data case, i.e. factor of 1.79 greater. The RMS pressures for the other nozzles are very similar in magnitude for both cases.

PSD comparisons of the predicted pressures are also provided in Figures 2 through 5. In these figures, the Missing Data case is designated QC2 Fewer SGs. These comparisons also show very similar pressure magnitudes for MSL A, MSL B and MSL D locations for all frequencies. This is especially true for the most predominate frequencies between 135 and 160 Hz. The MSL C comparison shows very similar frequency content for the two cases, but the magnitude of the Missing Data case is significantly higher than the All Data case. At 138 Hz, the Missing Data pressure is approximately 3.5 times greater than the All Data case. At 151 Hz, the Missing Data pressure is approximately 1.8 times greater than the All Data case.

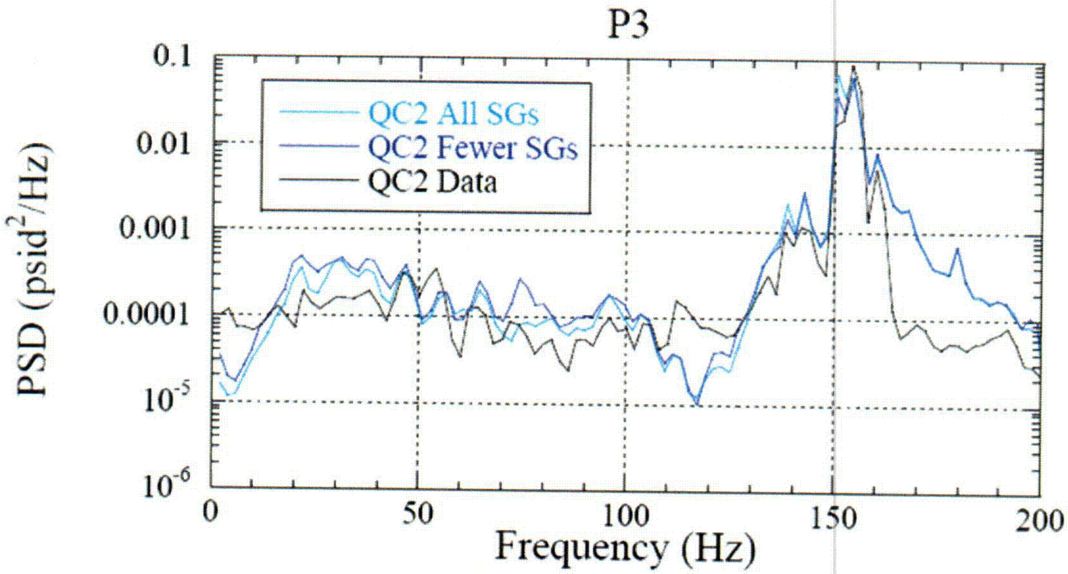

Figure 2: PSD Comparison Opposite MSL A

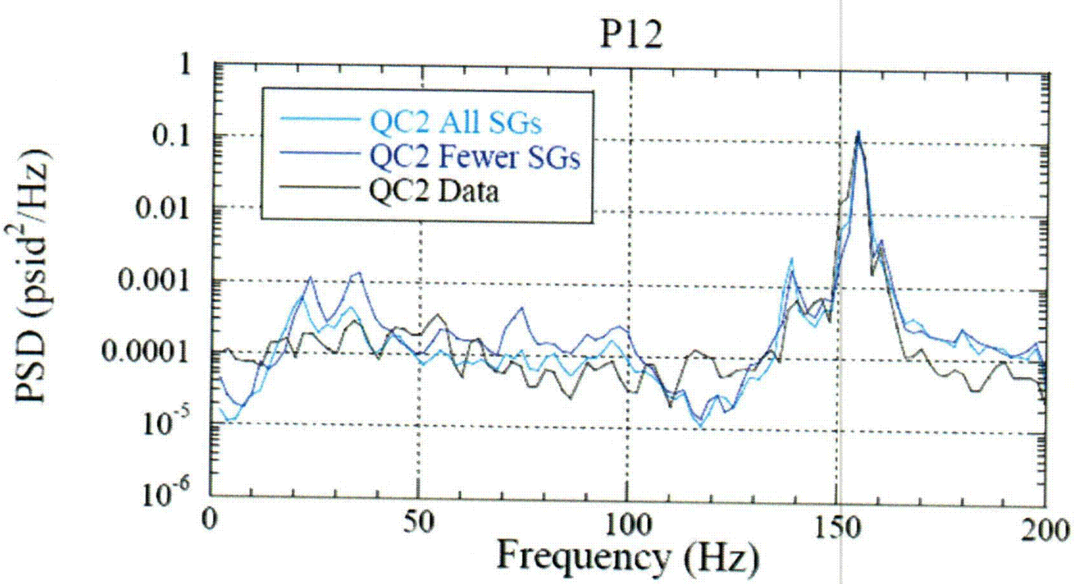

Figure 3: PSD Comparison Opposite MSL B

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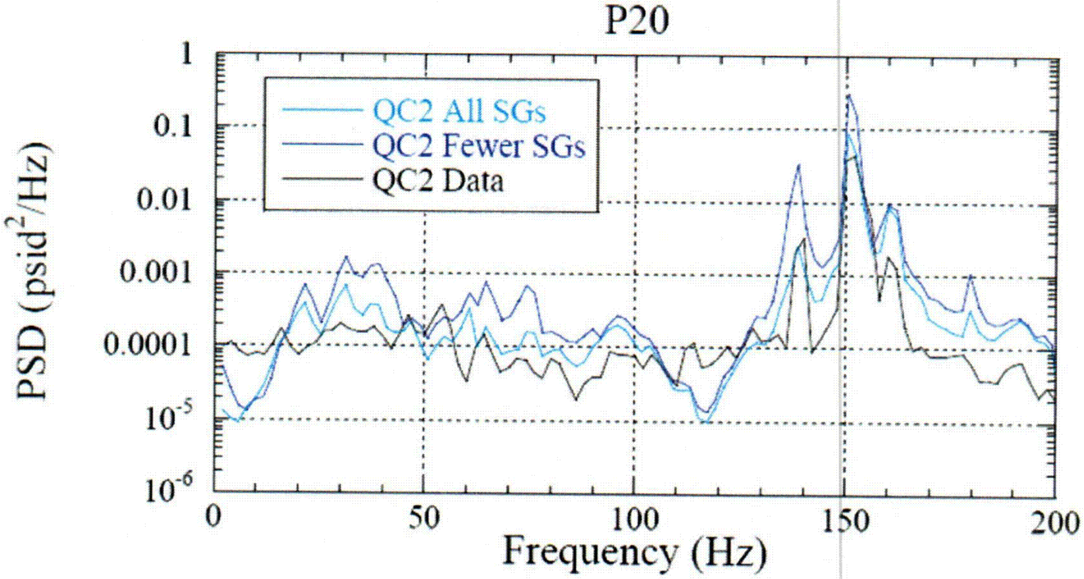

Figure 4: PSD Comparison Opposite MSL C

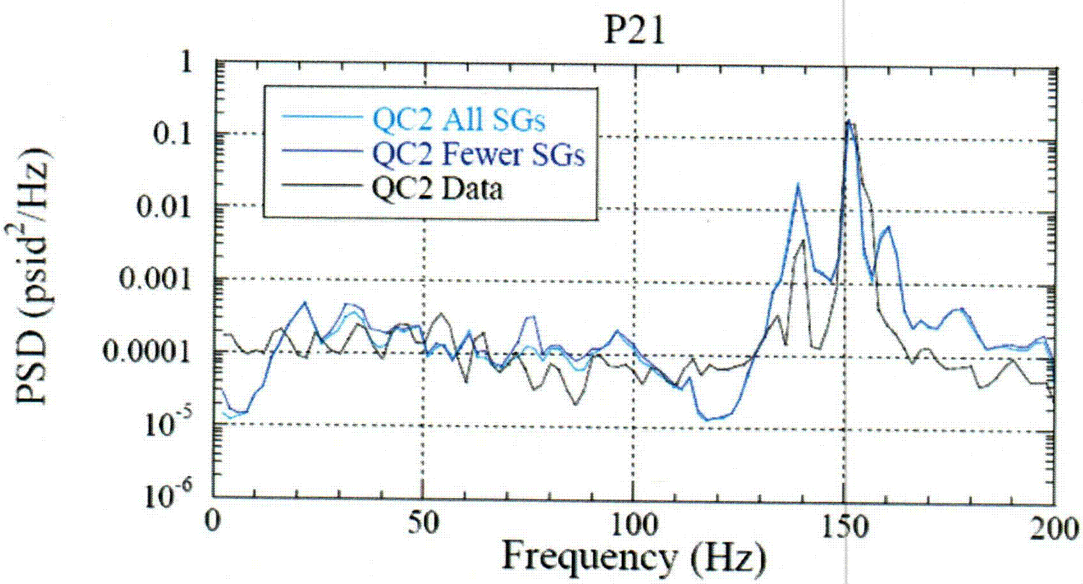

Figure 5: PSD Comparison Opposite MSL D

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5. Conclusions/Discussion

The strain gage data taken at comparable power levels on Unit 1 and Unit 2 have been compared. The following observations can be made:

1) In the three locations where all Unit 1 strain gages are operable and direct comparison can be made to Unit 2, (651B, 651D, 624D), the Unit 2 measurements are higher than Unit 1, both in RMS as well as peak strain measurement.
2) Single pair comparisons between the units suggests that comparable phenomena occur in both plants. Use of single pair data introduces a higher RMS and peak strain measurement. The increase in magnitude is not constant at all locations, as would be expected since the differences are due to local pipe modal response.
3) The strain gage data for Unit 1 651C and 624C show considerably higher strain measurements than what would be expected based on comparable Unit 2 single pair data, i.e. 1.8 times higher for the 651 location, and 1.35 times higher for the 624 location. Since the ratios at the two locations differ, it would suggest that the differences are likely the result of localized structural response of the piping and are not indicative of a large acoustic pressure difference. To wit, the Unit 1 C MSL acoustic pressures may in fact be somewhat larger than Unit 2, but are not more than a factor of 2 larger as suggested by the individual strain gage pair measurements. Alternate means of verification, using MSL venturi data are needed to confirm this.

The Acoustic Model for Unit 2 was exercised using equivalent single pair data reflective of the Unit 1 operable strain gage configuration with comparison to actual plant data measured. The following observations can be made:

1) Use of single pair data yields a conservative result when compared against plant data, e.g 1.8 times greater opposite the C main steam nozzle.

Taken in aggregate, the observations above support that the acoustic pressures in QC2 B and D steam lines are clearly higher than in the Unit 1 steam lines. The acoustic pressures in the A steam line are most likely comparable. The acoustic pressures in the Unit 1 C main steam line may be somewhat higher than those observed on Unit 2, but not a factor of 2 larger as is implied by the single strain gage pair measurement.

6. References

1. "Comparison Between QC1 and QC2 at EPU with Five Strain Gages Inoperative," Continuum Dynamics, Inc. Technical Note No. 05-31, Revision 0, dated June 15, 2005.