ENCLOSURE 2

Attachment 3

Exelon Report Number AM-2005-003, "Engineering Evaluation of Reduced Strain Gage Data Sets on the Quad Cities Unit 1 Test Condition 15A," dated June 29, 2005

Engineering Evaluation of Reduced Strain Gage Data Sets on the Quad Cities Unit 1 Test Condition 15A

Document Number AM-2005-003

Nuclear Engineering Department
Exelon Nuclear Generating Co.

Prepared by: Kevin B. Ramsden Date: 6/29/05

Reviewed by: Keith Moser Date: 6/29/05

Approved by: Robert Stachniak Date: 6/29/05
(Date Issued)

Abstract

This report documents the data review and engineering judgments applied to the strain gage data taken at QC1 during Test Condition 15A. The failure of 5 strain gages on 3 steam lines has been determined to have the potential to introduce erroneous pressure information into the Acoustic Circuit Model. The steps taken to confirm and appropriately address this condition are the principal content of this report.

1. Introduction

This report documents the evaluation performed and engineering judgments applied to the QC1 Test Condition 15A strain gage data, used as input information to the Acoustic Circuit Models. Specifically, the failure of 5 strain gages in 3 of the steam lines (A,B, and C) yielded a degraded data set that proved to be unusable without modification. The C-line data was the most seriously impacted, relative to the other lines and is the only data that has been determined necessary to be adjusted.

The effect of reducing the numbers of operable strain gages on the collected data was first noted in the first blind benchmark performed on QC 2 at 790 MWe [Reference 1]. The predicted data was based on the use of single pairs of strain gages at each location (2 locations per steam line, 651' and 624' elevations). The comparison to in-vessel measured pressure data showed that the single strain gage pair data yielded the key frequency content of the major acoustic loads (at 155 hz) reasonably. It further showed that significant frequency content not present in the in-vessel data appeared in the predictions. At approximately 80 hz, the prediction included a large magnitude peak that was not reflected in the plant data. Subsequent QC 2 predictions employed the combination of two strain gage pairs at each location, and the results showed that the 80 hz signal was effectively eliminated.

For the QC 1 Test Condition 15A data, a single pair of strain gages is available on the C-line at the 651' elevation. Review of the predicted pressures from this pair shows the same tendency as observed in QC 2, specifically the tendency to include large 80 hz frequency content. Since the opposite strain gage pair is faulted, the only options available are to use the data as is, or to apply correction to produce an appropriate load. The former approach was attempted without success, due to sensitivity of the structural model to excitations in the 80 hz range. Therefore the challenge is to produce a load that is appropriate for use in structural analysis.

2. Methodology

2.1 CDI Acoustic Circuit Analysis

The CDI acoustic circuit analysis methodology employs strain gage data taken at a minimum of two locations on each steam line to establish a boundary condition and then project an inlet condition at the reactor vessel nozzle, using transfer function methods. This approach captures sources in the steam lines as well as any present in the vessel, such as might be expected from a flow vortex entering the steam lines. The pressure field inside the vessel is calculated using a three dimensional Helmholtz equation solution and combining with the boundary conditions established at the nozzles. The output of the CDI analysis is the time dependent acoustic pressure field in the steam space of the reactor vessel. It is important to note that the acoustic circuit analysis is completely dependent on the dynamic pressure data derived from the strain gage data. If non-acoustic pressures are predicted at the strain gage locations, they will be transferred forward and imply false loading conditions on the steam dryer. The CDI methodology is documented in Reference 2.

2.2 QC 1 Test Condition 15A Description

2.2.1 Power level

Test Condition 15A was performed at a power level of 2887 MWt. It represents a maximum observed response achievable at the time of the testing.

2.2.2 MSL Strain Gauge Inputs:

Eight main steam line locations were instrumented with 16 pairs of strain gauge for the acoustic circuit analysis.

- MSL "A" Elevation 651 S1/S3 pair — Elevation 624 S5/S5a pair
- MSL "B" Elevation 651 S7/S9 pair — Elevation 624 S11/S11a pair
- MSL "C" Elevation 651 S31/S33 pair — Elevation 624 S35/S35a pair
- MSL "D" Elevation 651 S37/S39 pair — Elevation 624 S41/S41a pair

- MSL "A" Elevation 651 S2/S4 pair — Elevation 624 S6/S6a pair
- MSL "B" Elevation 651 S8/S10 pair — Elevation 624 S12/S12a pair
- MSL "C" Elevation 651 S32/S34 pair — Elevation 624 S36/S36a pair
- MSL "D" Elevation 651 S38/S40 pair — Elevation 624 S42/S42a pair

The failed strain gages in the TC 15A test data condition are:

S3 (MSL "A" Elevation 651)
S6 (MSL "A" Elevation 624)
S11a (MSL "B" Elevation 624)
S31 (MSL "C" Elevation 651)
S36 (MSL "C" Elevation 624)

2.2.3 In-Vessel Instrumentation

No In-vessel instrumentation was employed in the development of the dryer pressure loads on QC 1. High speed pressure data was recorded for the vessel level instrument taps (59A and 59B) located in the dryer skirt region. This data will be used to provide understanding of the acoustic pressure field being experienced in the vessel.

2.1.1 Additional MSL Instrumentation

In addition to the strain gage placements described above, there were accelerometers installed and monitored on the Electromatic Relief Valve on line C. The data from these instruments will be reviewed for frequency content.

3. Calculations

3.1 Calculation Approach

Fast Fourier Transform were generated to allow characterization of the frequency content and power spectral density (PSD) of the strain gage data at both locations on the C MSL, as well as the vessel level tap data. The PSDs were generated using sample groups of 2000 samples per group, based on the data time step. Frequency content up to 200 hz was calculated to coincide with the frequency interval calculated by CDI and applied in the structural loads calculations.

The intent of the comparisons performed at multiple locations is to demonstrate whether non-acoustic loads are being introduced into the strain gage data at the remaining C MSL strain gage pair, and to determine an appropriate reduction factor if justified. The principal criteria applied in this evaluation are:

1. True acoustic pressure signals will be observed to propagate. Evidence of propagation will be sought in the vessel level tap data and the C MSL 624' elevation data.
2. Non-acoustic signals may be reduced to the general background amplitude of adjacent frequencies, but not below comparable data on the fully instrumented D MSL.
3. The frequency range for which a data correction is applied will be minimized to the maximum extent possible.

4. Results

The following section describes the data reviewed and the observations that resulted.

4.1 Observations from the U-2 790 MWe Blind Comparison and Model Correction

4.1.1 Model Configuration

The CDI model for this case applied single strain gage pair data only for the blind comparison. The revised case applied both strain gage pairs at each measurement location. 60 and 180 hz narrowband noise was also filtered.

4.1.2 Comparison of the Blind to the Revised Case

Plots of the predicted vs. measured pressures at sensors P-20 and P-21 for the QC 2 790 MWe blind benchmark and the revised case are shown in Figures 1 through 4. Sensors P-20 and P-21 are on the dryer cover plate adjacent to the C and D MSLs. As noted above, the principal difference in the analytical prediction was the incorporation of both sets of strain gage data at each location measured. The blind comparison, based on a single pair showed significant signal strength at the 80 hz location, that was not reflected in the plant data. The revised calculation, employing both pairs of strain gages, shows a much more appropriate, although still conservative representation of the plant data at the 80 hz range. The following observations are salient:

1) Use of a single strain gage pair in estimating dynamic pressures in the MSL may yield signal frequency content that is not representative of the actual plant acoustic loading.
2) The plant data suggests that there is little or no acoustic loading at the 80 hz frequency range. Indicated pressure loads at this frequency range appear to be in the noise levels of the instrumentation.

4.2 Unit 1 TC 15A C MSL Single SG Pair Prediction

The PSD of the single pair prediction for the 651' location on C MSL is shown in Figure 5. In Figure 6, this data is shown with similar data taken from the B and C MSLs on QC 2 where two pair data combination was performed. What is readily apparent is that the QC 1 C MSL strain gage data shows a large 80 hz signal that is not seen in either of the comparable QC 2 MSL points plotted. The 80 hz signal is large relative to the 157 hz acoustic loads present on all signals. As noted above, initial structural analyses based on the single pair data that utilized only a simplified amplitude correction based on the 157 hz signal strength were performed and showed that the structure was sensitive to 80 hz signal content. Therefore, conservatively ignoring the included signal has been considered and shown not to be a practical approach.

4.3 Vessel Level Sensor Pressure Tap Data

The vessel level taps are located in the dryer skirt region and provide an independent means of confirming the frequency content of the vessel pressure field. The data was taken simultaneous with the strain gage data. Figures 7 and 8 show the PSD plots of the CH59A and CH59B vessel level taps. What is clear from these plots is that the large acoustic load at approximately 157 hz is clearly present and dominant. The figures show that there is little if any signal present in the 80 hz range. This suggests that the 80 hz signal in the C MSL 651' pair is not the result of a propagating acoustic pressure. In contrast the 157 hz signal is clearly a propagating acoustic pressure.

4.4 C MSL 624' Elevation Data

Figure 9 shows the PSD of the response of the functioning strain gage pair at the 624' elevation of the C MSL. Comparison of this plot to the 651' data on the same steam line in Figure 5 is beneficial. The following observations can be made:

1) There is some 80 hz content, but it is very near the background level.
2) The 140 hz signal component is more prominent at this location than the 157 hz signal.

These observations support that there is not a large propagating 80 hz acoustic pressure. The variation in the in the 140 hz vs 157 hz signals suggests that acoustic node points may be a factor. Therefore, this data point does not provide a singularly compelling argument by itself.

4.5 C MSL Accelerometer Data

Figures 10, 11, and 12 provide the x,y, and z direction acceleration vs frequency data for locations at the ERV on the C MSL. The accelerometers clearly show the 140 hz and 157 hz signals. These signals are the only peaks that show in all three axes, which is consistent with the large magnitude of these signals evidenced in other data provided. There is little or no 80 hz signal component in any of the accelerometer data. The lack of 80 hz components suggest that there is no propagating acoustic pressure at this frequency. Since this location is fairly near to the 624' elevation strain gage pair, it supports that the absence of 80 hz signal component in the strain gage data is due to the absence of a propagating signal, and not due to accidental location at an acoustic node point.

5. Conclusions/Discussion

This report has demonstrated the following:

1) Use of a single pair strain gage reading vs multiple pairs can introduce non-acoustic signals into the dynamic pressure time history being developed. This was demonstrated in the QC 2 790 MWe blind benchmark and revised 790 MWe predictions.
2) A large 80 hz signal is present in the single pair data developed from the QC 1 C MSL 651' location.
3) Vessel level tap pressure data suggests that there is no significant 80 hz signal present in the QC 1 dryer skirt region. This is consistent with observations at QC 2.
4) Review of the frequency response at the C MSL 624' elevation does not show evidence of propagating 80 hz signals.
5) The accelerometer data from the C MSL ERV location shows no evidence of 80 hz signal.

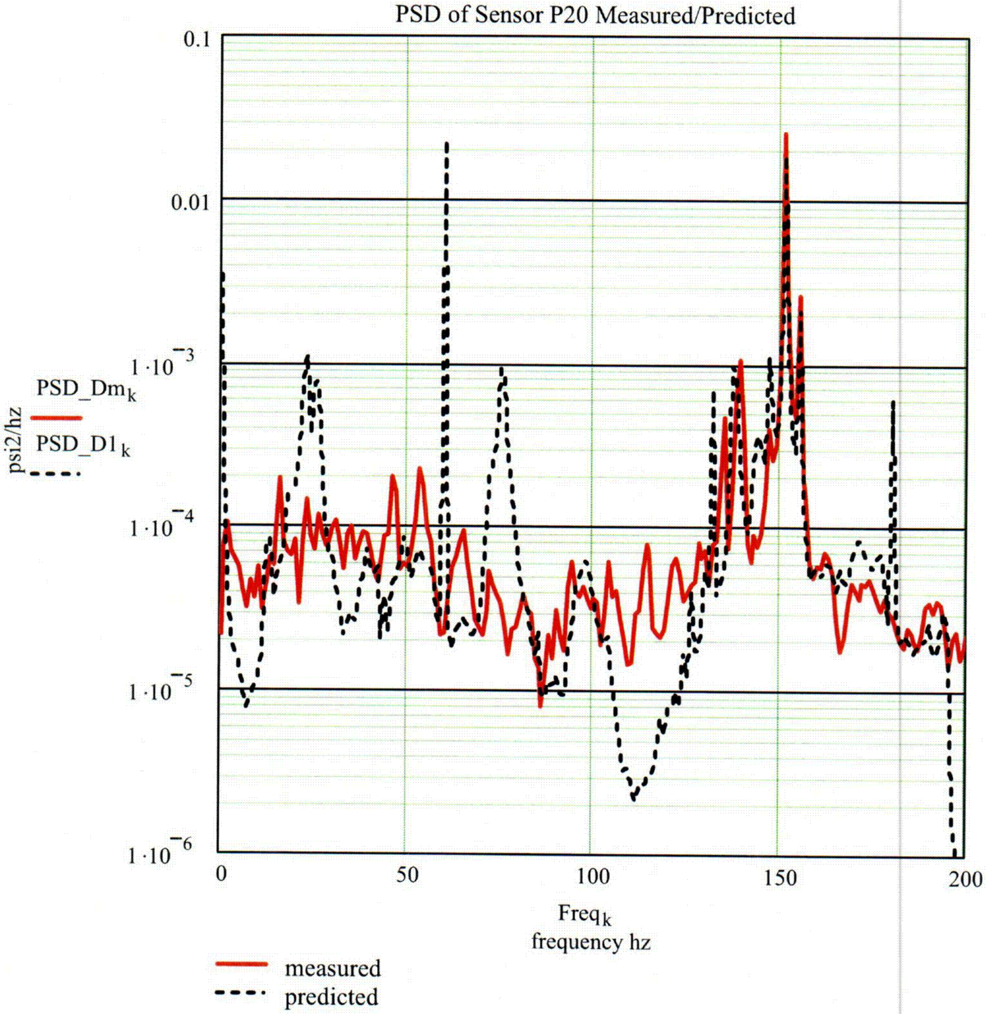
These findings support the conclusion that the 80 hz signal in the C MSL 651' elevation is a result of local structural effects and does not reflect a propagating acoustic pressure. Therefore, if the single pair strain gage data must be used for dryer load prediction, it is appropriate to reduce the 80 hz signal to a level comparable to that of adjacent frequencies.

6. References

1. "Acoustic Circuit Benchmark Quad Cities Unit 2 Instrumented Steam Path 790 MWe and 930 MWe Power Levels", Exelon Report AM-2005-002, Dated June 6/15/05

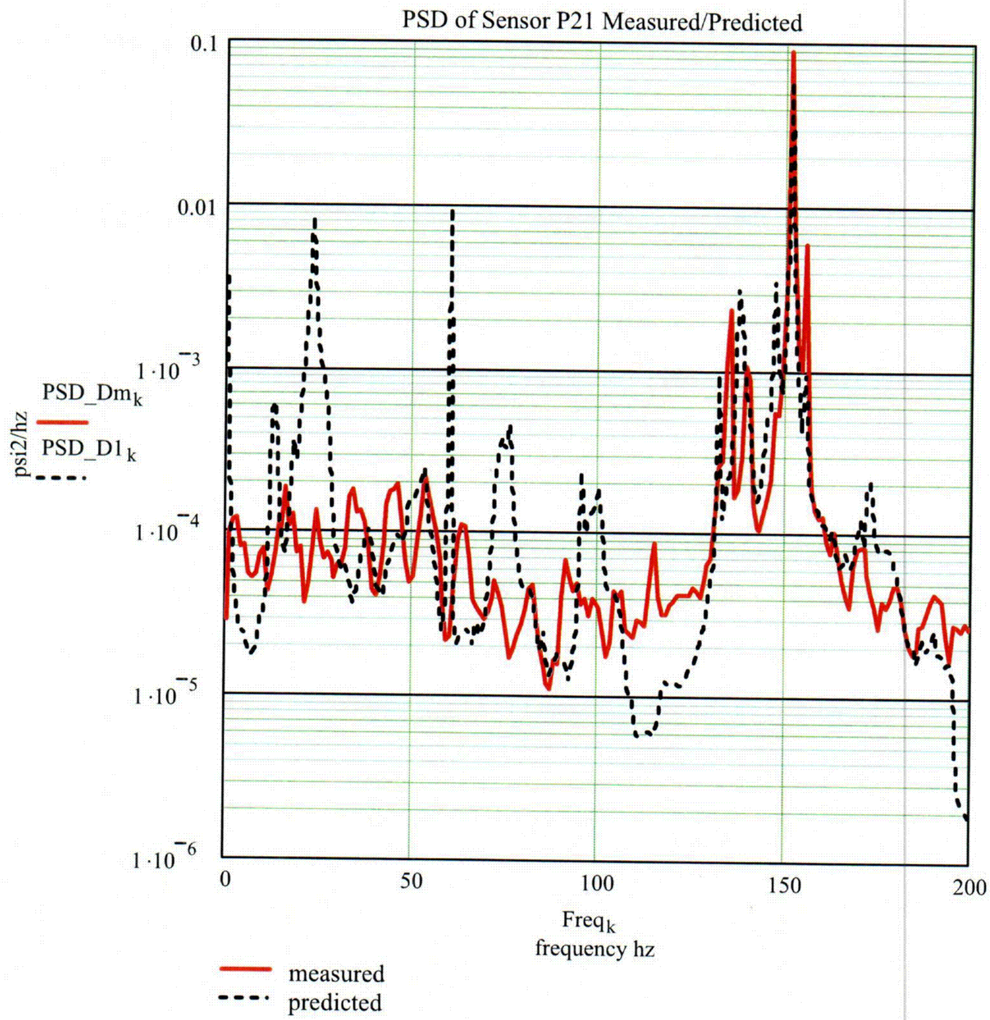
2. "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," CDI Report 04-09, May 2004.

Figure 1 Sensor P-20 CDI 790 MWe Prediction PSD



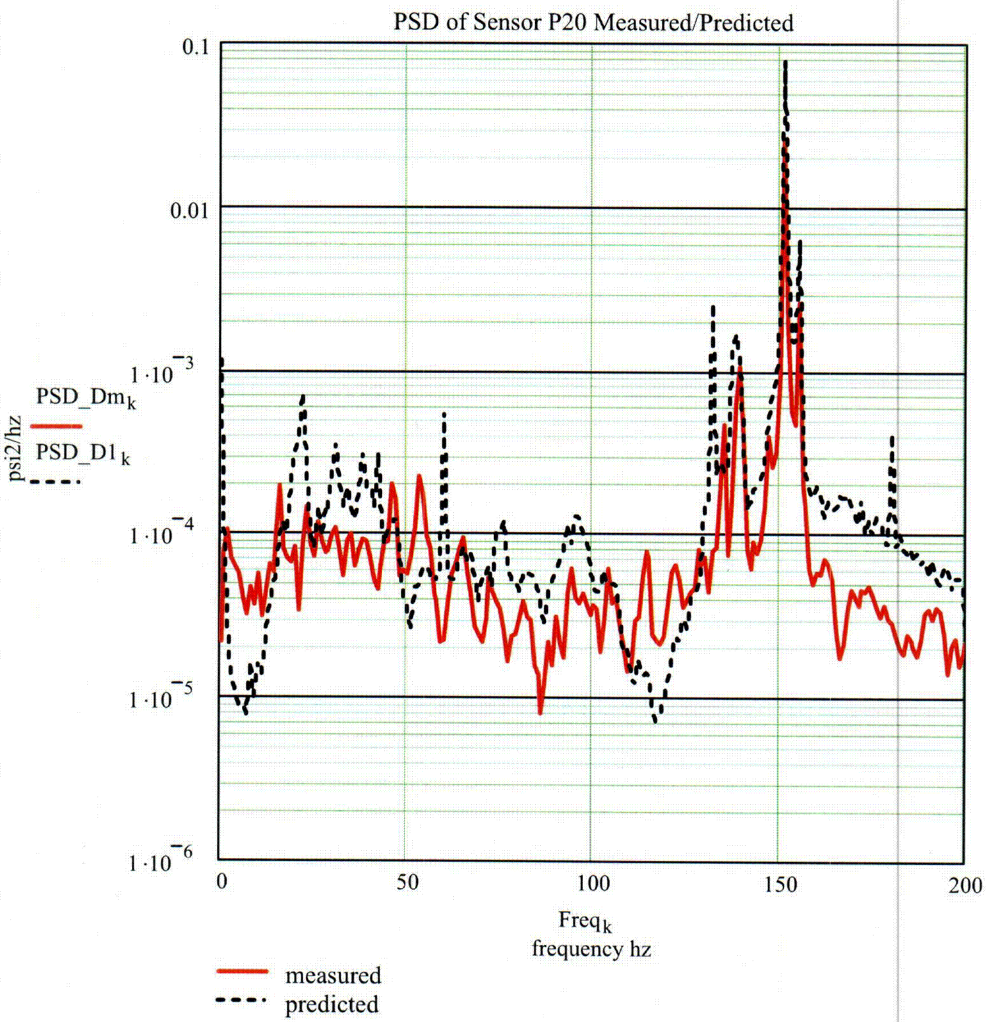
C01

Figure 2 Sensor P-21 CDI 790 MWe Prediction PSD



C02

Figure 3 Sensor P-20 CDI 790 MWe Prediction PSD Revised



C03

Figure 4 Sensor P-21 CDI 790 MWe Prediction PSD Revised

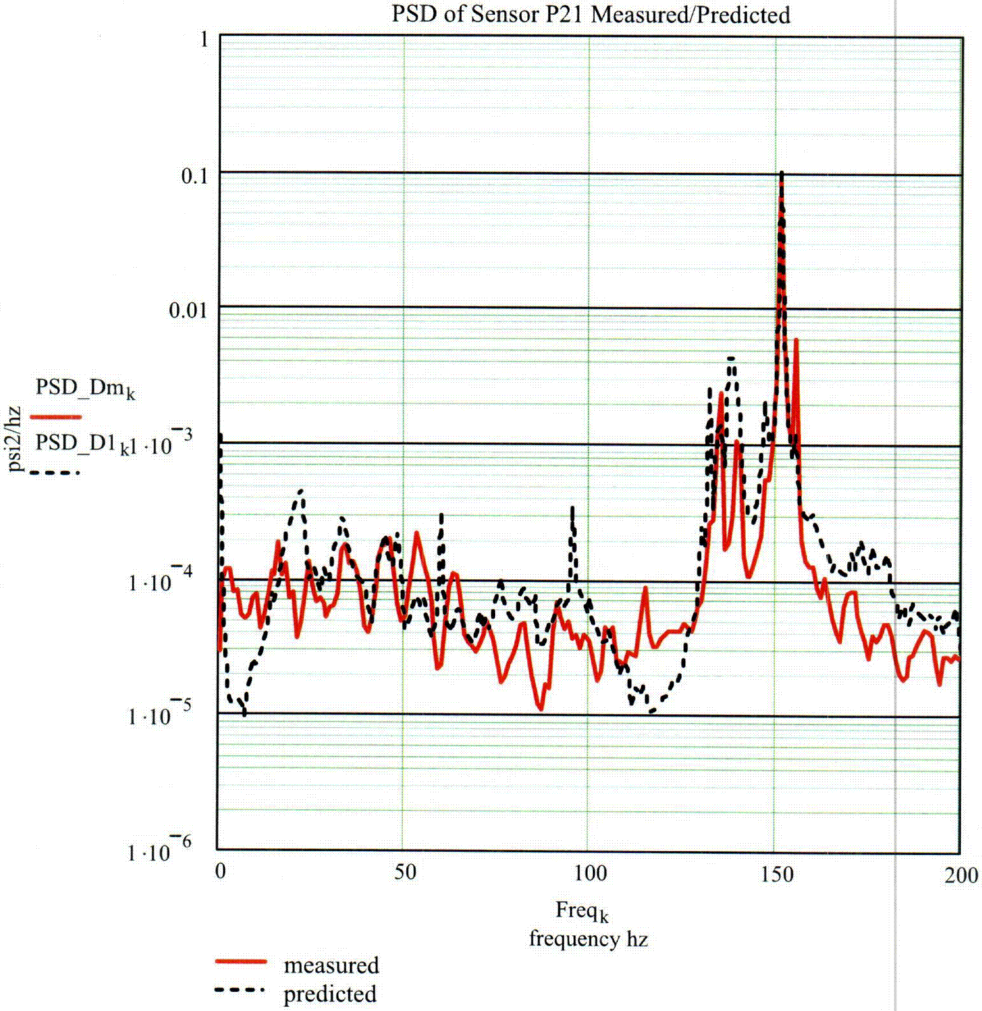
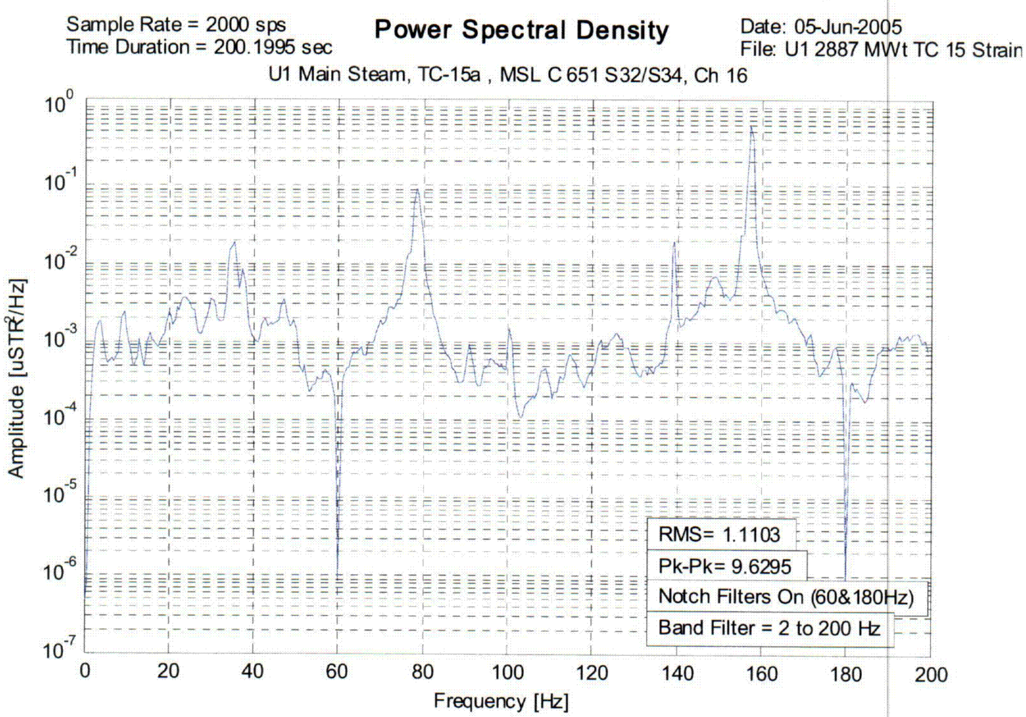
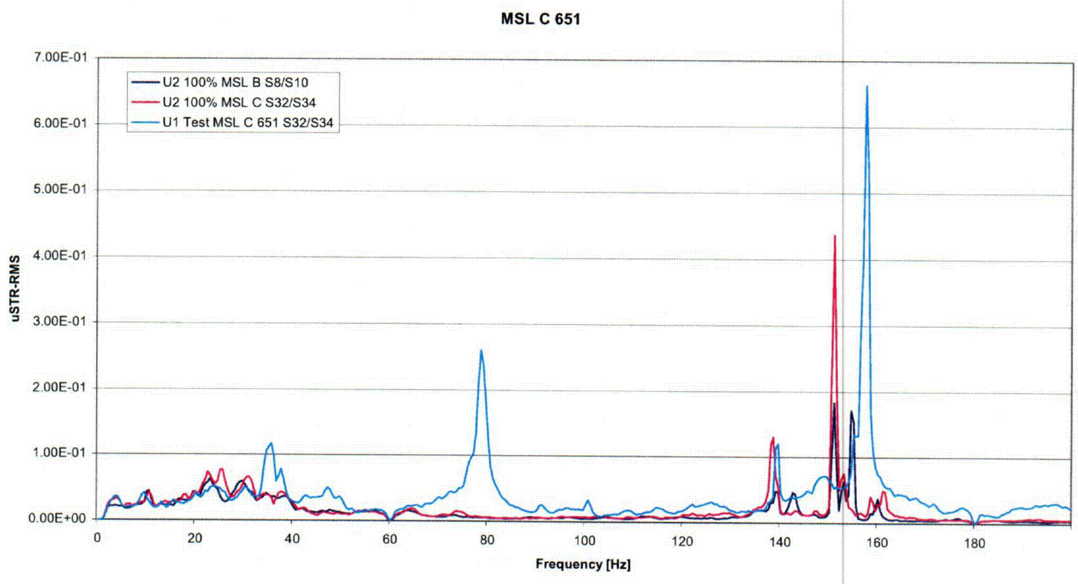


Figure 5 U-1 C MSL 651' Single Pair data



C05

Figure 6 Comparison of QC C MSL Single Pair Data to Q2 Two Pair Based Data



C06

Figure 7 PSD of Vessel Level CH 59A

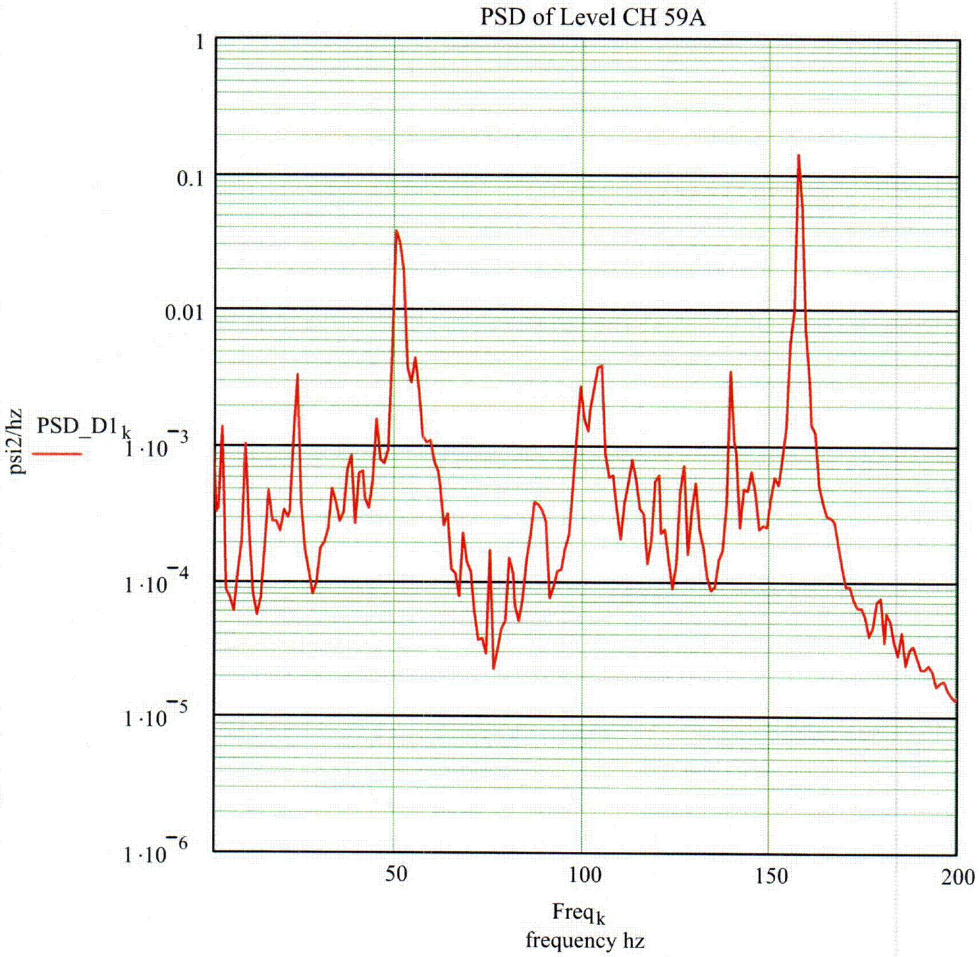
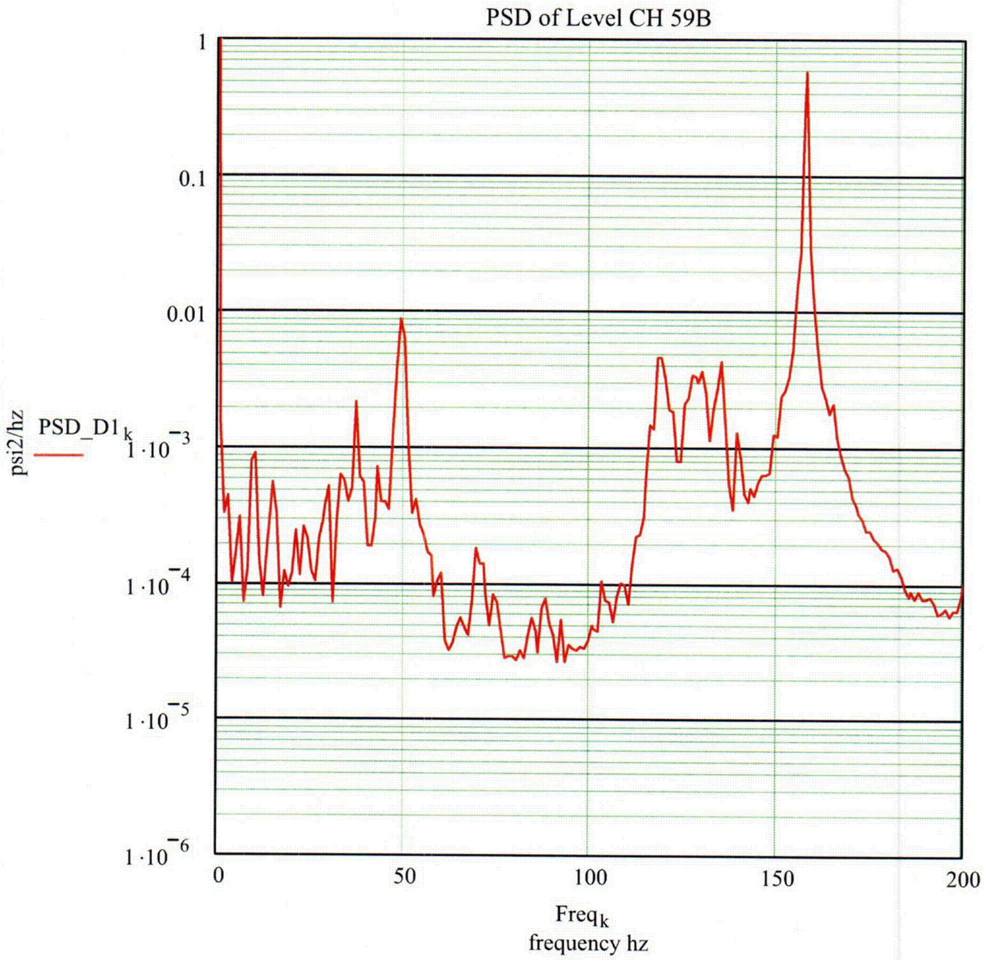
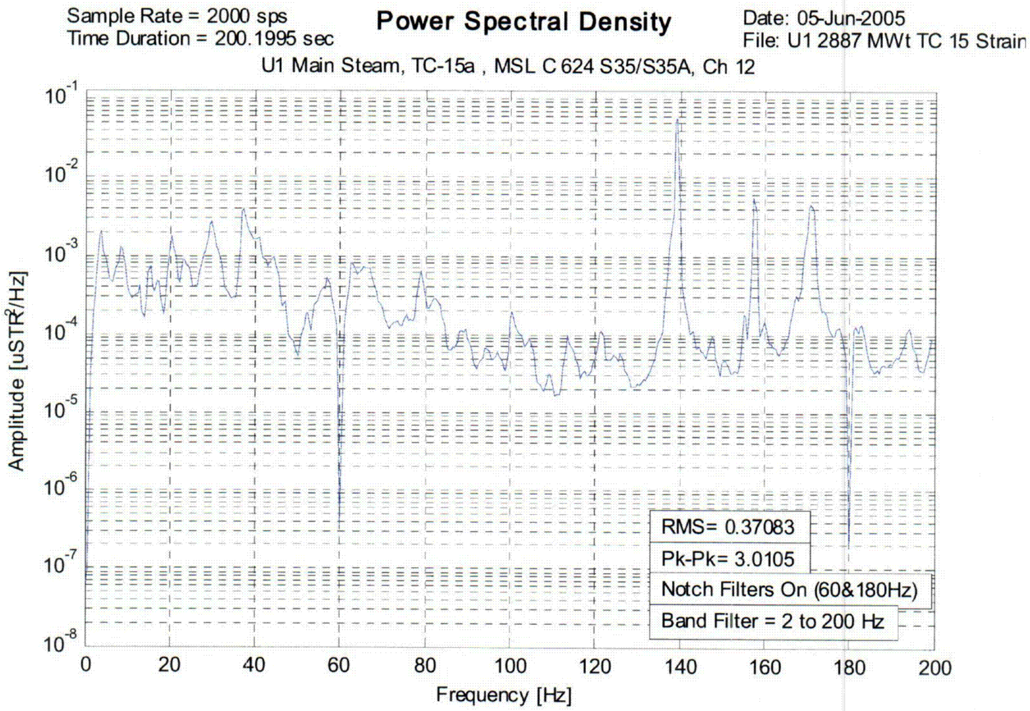


Figure 8 PSD of Vessel Level CH 59B



C08

Figure 9 QC 1 C MSL 624' Elevation Single Pair Data



C09

Figure 10 QC 1 C MSL ERV Accelerometer Data (X-direction)

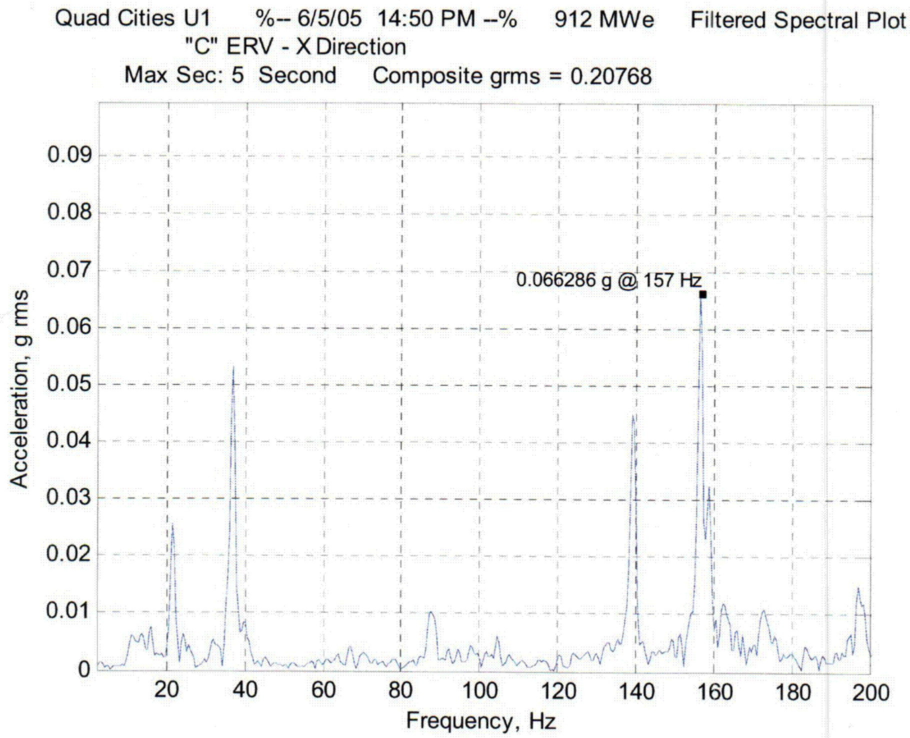


Figure 11 QC 1 C MSL ERV Accelerometer Data (Y-direction)

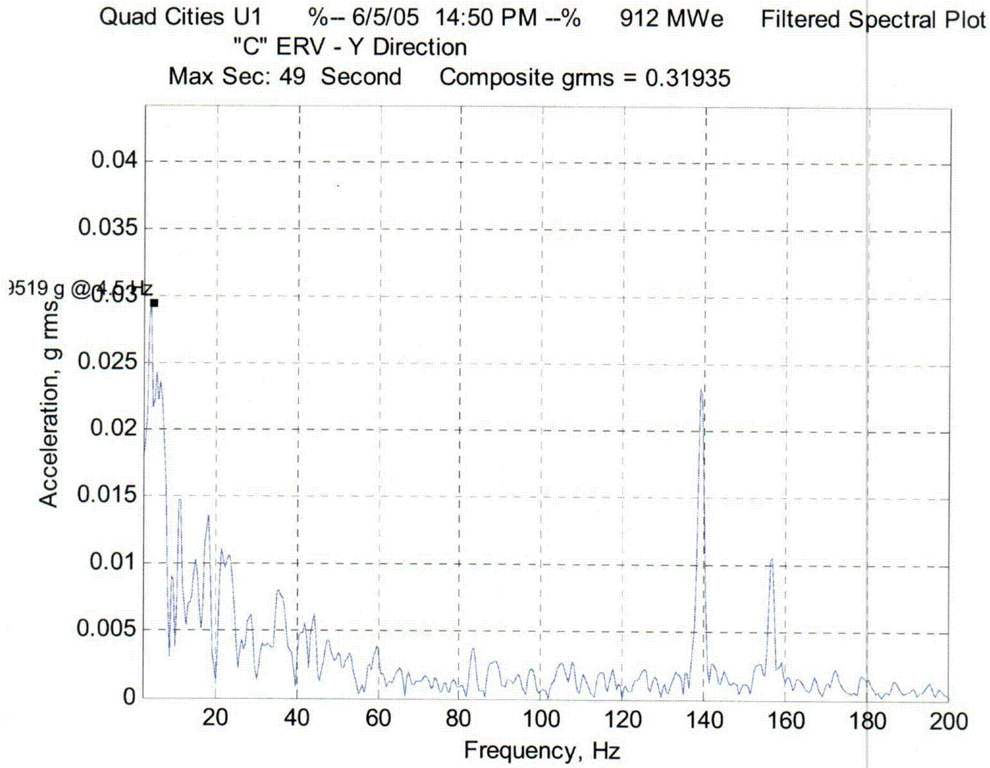
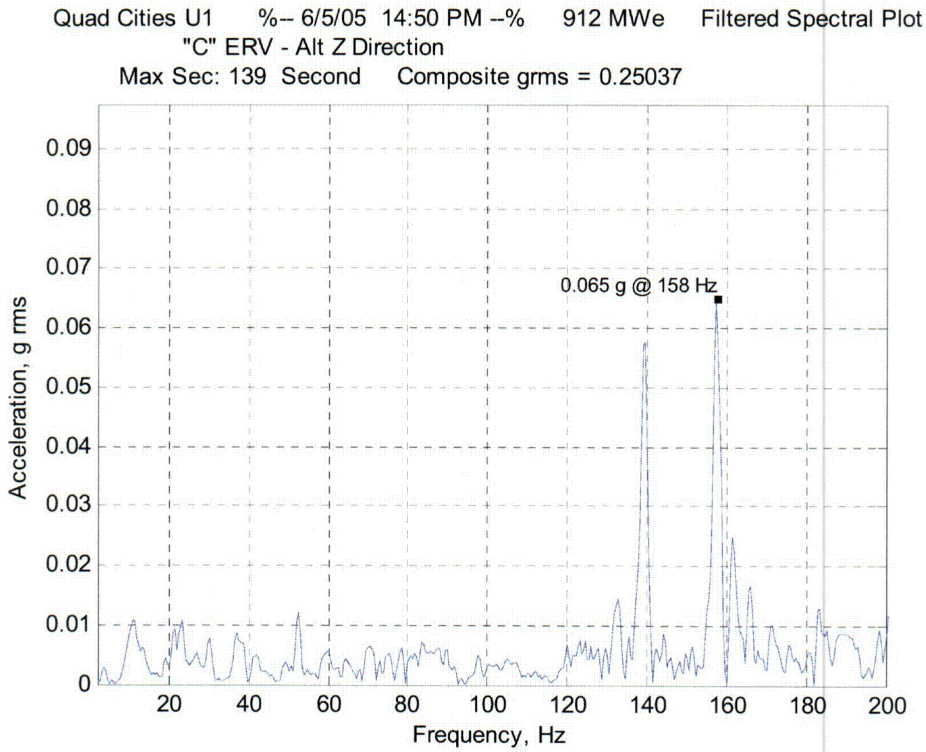


Figure 12 QC 1 C MSL ERV Accelerometer Data (Z-direction)



C12