CDI Technical Note 06-26
Use of One-eighth Scale Data to Evaluate Substitution of Failed Strain Gages in In-Plant Data
Revision 0, dated September 2006

C.D.I. Technical Note No. 06-26

Use of One-Eighth Scale Data to Evaluate Substitution of Failed Strain Gages in In-Plant Data

Revision 0

Prepared by

Continuum Dynamics, Inc.
34 Lexington Avenue
Ewing, NJ 08618

Prepared under Purchase Order No. 4500341046 for

Nuclear Business Unit, PSEG Nuclear LLC
Materials Center, Alloway Creek Neck Road
Hancocks Bridge, NJ 08038

Approved by

Alan J. Bilanin

Reviewed by

Milton E. Teske

September 2006

Summary

Data collected at Hope Creek Unit 1 during current licensed thermal power (CLTP) suffered from the failure of several strain gages on the C and D main steam lines. The remaining data can still be used, but only if the missing data are replaced by data taken on the A and B main steam lines. This technical note summarizes a technique used previously [1] to perform such a substitution and quantify the amount of conservatism that is added to a steam dryer load resulting from this substitution.

Introduction

Strain gages were mounted on the four main steam lines at Hope Creek Unit 1 (HC1), and data were collected at CLTP conditions in May 2006. Upon analysis, it was found that the lower C and D main steam line strain gages failed during data collection [2]. One way to make use of the data on the A and B main steam lines is to recognize the symmetry of the steam lines exiting the steam dome and replace the failed data on main steam line D with the usable data on main steam line A, and replace the failed data on main steam line C with the usable data on main steam line B. Geometry considerations support this substitution with regard to main steam line length and standpipe locations; however, phasing information is generally lost when main steam line history signals are replaced.

The way to overcome this phasing problem is to shift the phase of the time signal on main steam lines C and D to maximize the load on the dryer, resulting in a conservative load prediction. This step is accomplished by shifting the time from main steam lines C and D together, then from main steam line C separately, then from main steam line D separately, until the maximum load on the dryer is found. This maximum low resolution load then establishes the phase of the signals on the C and D lines so as to maximize the dryer loading. This approach was followed to compute the CLTP load on the HC1 dryer; details may be found in [1].

The load created by this substitution approach is expected to be conservative. In an effort to quantify this conservatism, an additional calculation was undertaken in [1] by making use of data collected on a similar plant (Susquehanna Unit 1) at nearly identical steaming conditions. Recent in-plant strain gage measurements were made at Susquehanna Unit 1 (SQ1) to predict their CLTP dryer loads [3]. All eight strain gages were operational throughout these tests. The SQ1 data were manipulated, as discussed above, and a conservatism factor of 1.33 (33%) was obtained.

Even though the HC1 and SQ1 steam delivery geometries are nearly identical geometrically, it is natural to ask whether a set of data more representative of the HC1 geometry could be used to quantify the conservatism factor. To that end, this report summarizes the use of the substitution approach on the $1/8^{th}$ scale HC1 data [4] and the conservatism factor that results.

Approach

HC1 subscale data were collected at several main steam line Mach numbers, as shown in Table 1 and described in detail in [4]. Since the Mach number at the safety valve standpipe was not directly measured in the subscale tests, several runs were made at progressively larger flow speeds, all referenced to the Mach number anticipated at CLTP conditions at the entrance to the main steam lines. Results shown in this report have all been converted from subscale to full scale pressures and time.

Table 1. One-eighth scale test data summary.

C.D.I. Test Number	Mach Number
hc2-25	0.9 × CLTP
hc2-23	CLTP
hc2-21	1.12 × CLTP
hc2-32	1.25 × CLTP
hc2-34	1.35 × CLTP
hc2-36	1.45 × CLTP

The substitution procedure described below was applied to each of the six datasets. For the purposes of illustration, only the CLTP conditions are detailed in this report.

The time histories of the eight main steam line pressures, from 2.0 to 2.2 seconds for clarity, are shown in Figure 1 (the entire time histories from 0.0 to 5.82 seconds were used in the analysis). The substitution procedure is as follows:

1. The original data was processed by the acoustic circuit model to determine the maximum load on the dryer (1.0314 psid).

2. The C and D main steam line data were replaced by the B and A main steam line data, respectively, and the maximum load on the dryer was determined (0.7783 psid).

3. The A and B main steam line data were replaced by the D and C main steam line data, respectively, and the maximum load on the dryer was determined (1.3382 psid). Since this load is appreciably higher than the load found at step 2, the step 3 configuration was explored further.

4. The A and B main steam line data were phase-shifted, until the maximum load on the dryer was determined. The maximum load was found when the A and B main steam line data were shifted by nine time increments (1.5387 psid).

5. The A and B main steam line data were each phase-shifted around this time location, in an effort to obtain a higher maximum load. No such higher load was found in this case.

Thus, by this procedure the conservatism found by replacing $1/8^{th}$ scale main steam line data at CLTP conditions results in a factor of 1.49 on the maximum load on the dryer.

By way of illustration, the final time histories on the A and B main steam lines are compared with the original time histories in Figure 2, and with the original time histories on the D and C main steam lines, respectively, in Figure 3. The maximum load and RMS, as computed by the acoustic circuit model, are compared in Figure 4.

Results

A similar phase shift was undertaken for the remaining datasets shown in Table 1. For the test conditions including and above $1.12 \times$ CLTP, the replacement of the C and D main steam line data by the B and A main steam line data, respectively, resulted in higher loads (step 2 determined a higher maximum load than step 3). The overall result for the maximum load and the average RMS is shown in Figure 5. While the minimum conservatism factor is 1.29 for the maximum pressure load and the minimum conservatism factor is 1.21 for the average RMS, the average maximum pressure load across the data range examined is 1.41, as is the average RMS factor. These results are quite comparable to the SQ1 results previously determined to be 1.33 in [1].

References

1. Continuum Dynamics, Inc. 2006. Hydrodynamic Loads at CLTP on Hope Creek Unit 1 Steam Dryer to 200 Hz (Rev. 1). C.D.I. Report No. 06-17.

2. Structural Integrity Associates, Inc. 2006. Hope Creek Main Steam Line Strain Gage Data Reduction. Calculation File No. HC-28Q-302.

3. Continuum Dynamics, Inc. 2006. Hydrodynamic Loads at OLTP, CLTP, and 113% OLTP on Susquehanna Unit 1 Steam Dryer to 250 Hz (Rev. 0). C.D.I. Report No. 06-22.

4. Continuum Dynamics, Inc. 2006. Estimating High Frequency Flow Induced Vibration in the Main Steam Lines at Hope Creek Unit 1: A Subscale Four Line Investigation of Standpipe Behavior (Rev. 1). C.D.I. Report No. 06-16.

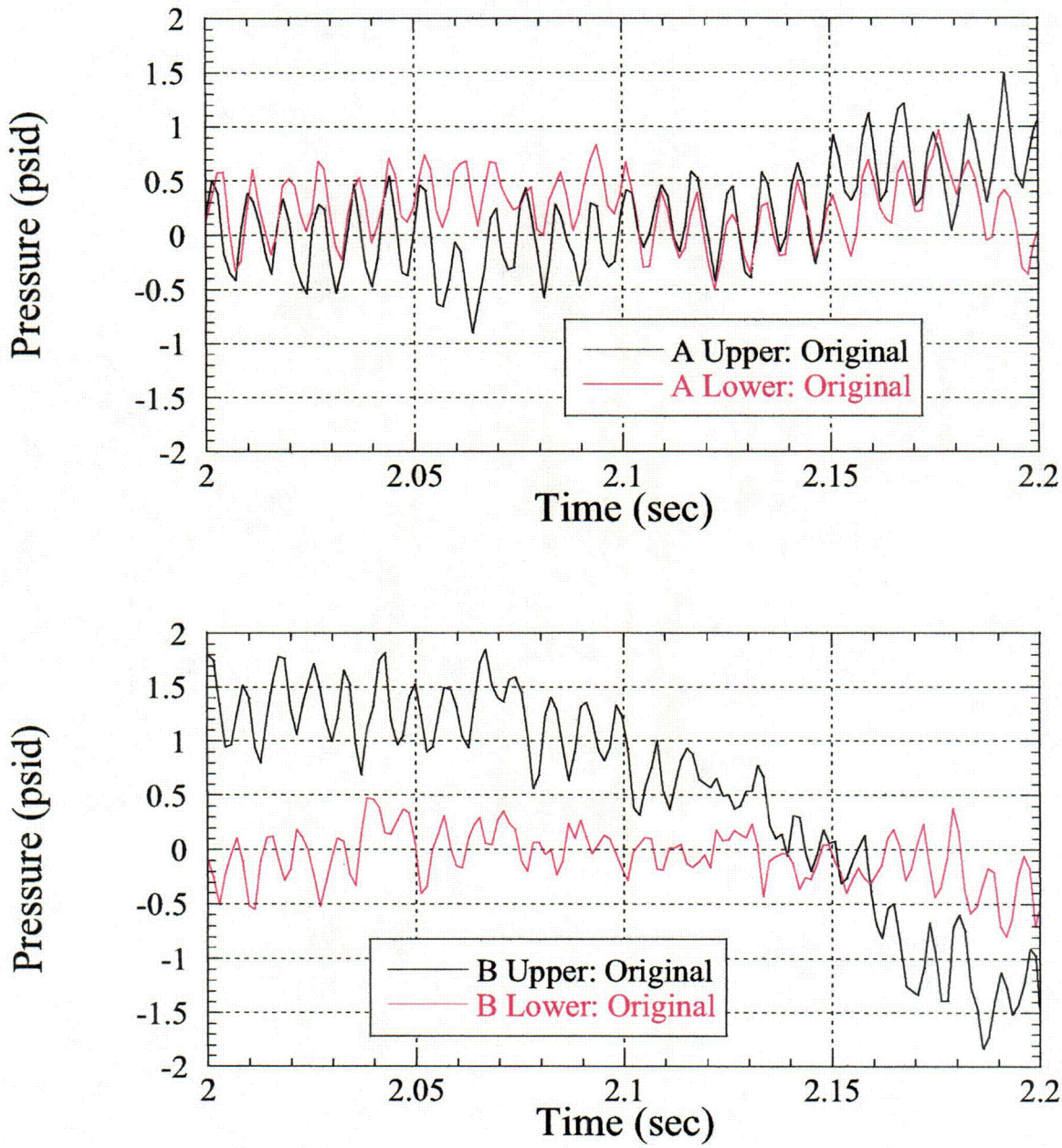


Figure 1. The measured (original) time histories on the A (top) and B (bottom) main steam lines for subscale test no. hc2-23 (CLTP conditions). The upper strain gage data are shown in black, while the lower strain gage data are shown in red. It may be seen that the signal from the upper A strain gage leads the signal from the lower A strain gage, while the upper B strain gage signal lags the signal from the lower B strain gage.

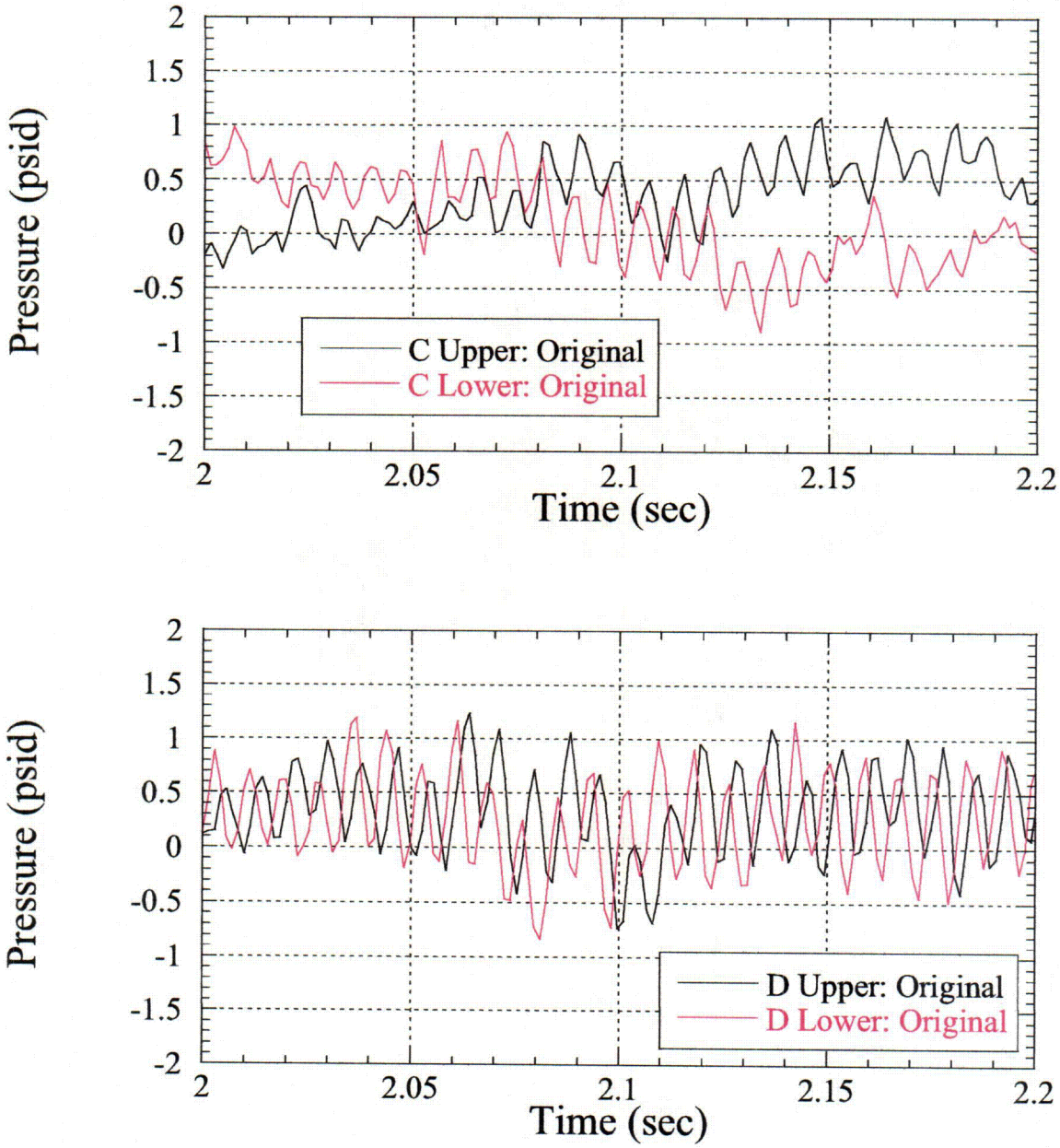


Figure 1 (continued). The measured (original) time histories on the C (top) and D (bottom) main steam lines for subscale test no. hc2-23 (CLTP conditions). The upper strain gage data are shown in black, while the lower strain gage data are shown in red. It may be seen that the signals from the upper C and D strain gages lag the signals from the lower C and D strain gages.

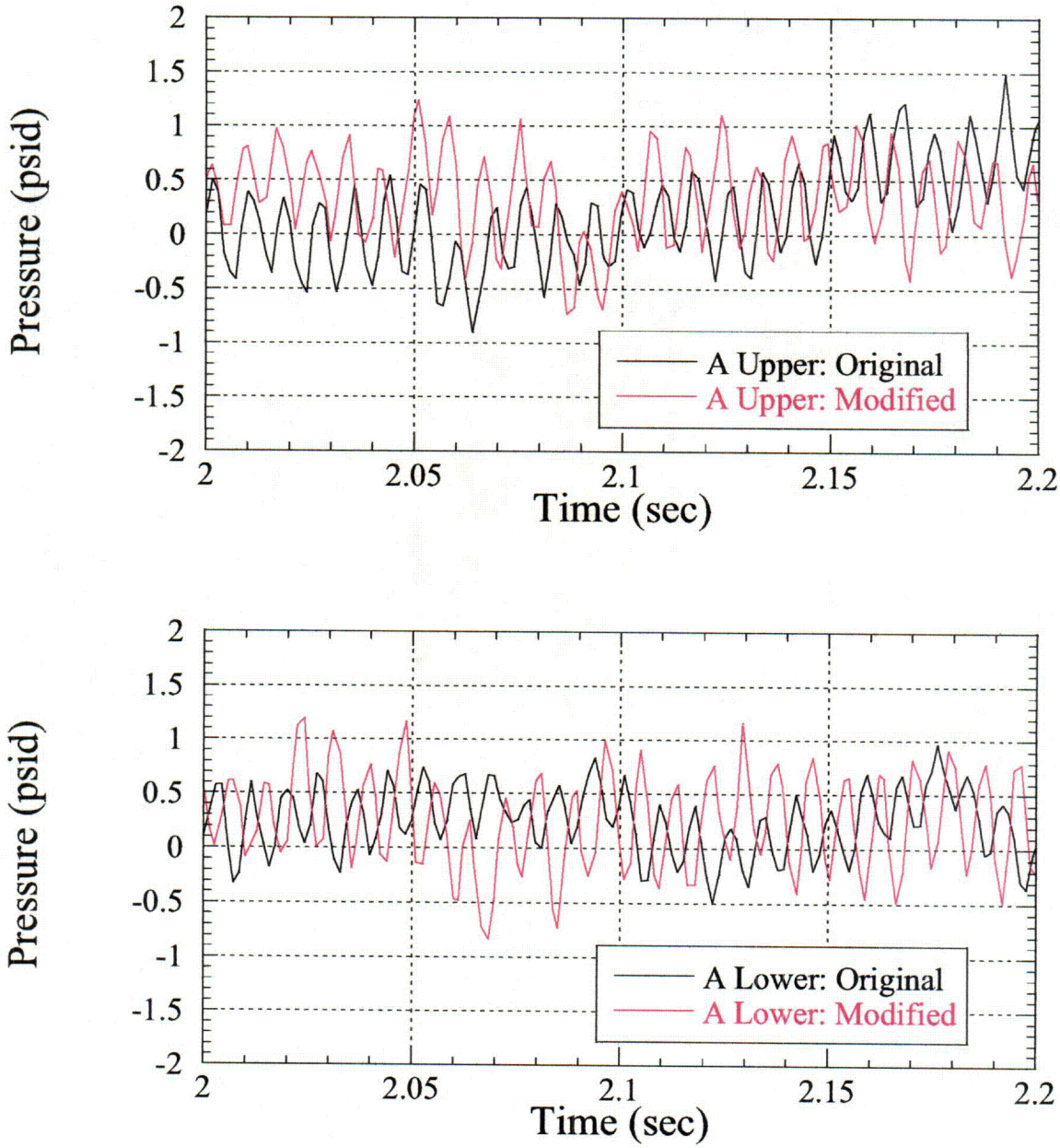


Figure 2. The measured (original) time histories on the A main steam line, compared to the modified time histories on the A main steam line after phase-shifting. The original strain gage data are shown in black, while the modified strain gage data (phase-shifting the D main steam line data) are shown in red. Nine time increments have moved the modified signals 0.0128 seconds back in time in these figures.

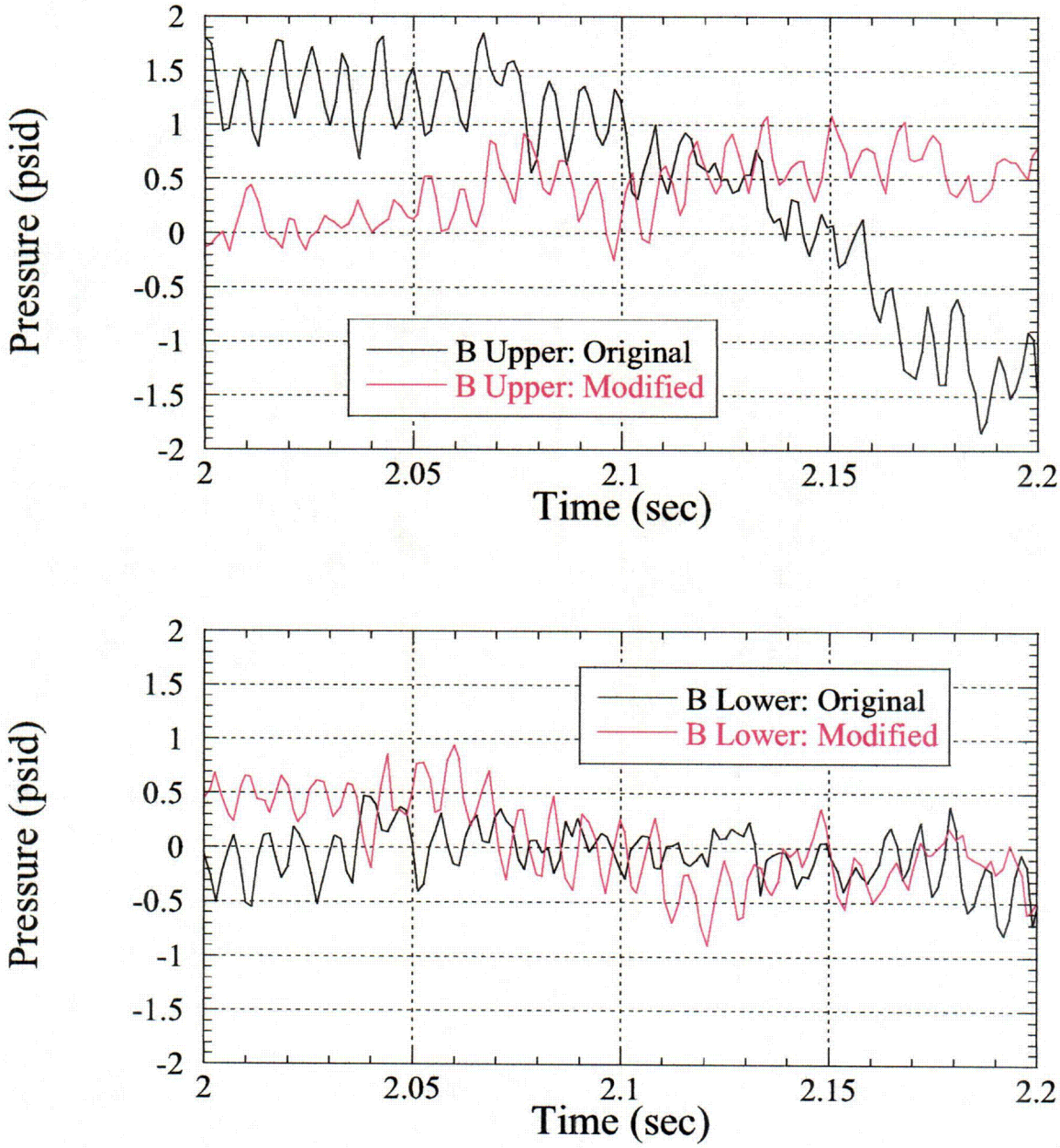


Figure 2 (continued). The measured (original) time histories on the B main steam line, compared to the modified time histories on the B main steam line after phase-shifting. The original strain gage data are shown in black, while the modified strain gage data (phase-shifting the C main steam line data) are shown in red. Nine time increments have moved the modified signals 0.0128 seconds back in time in these figures.

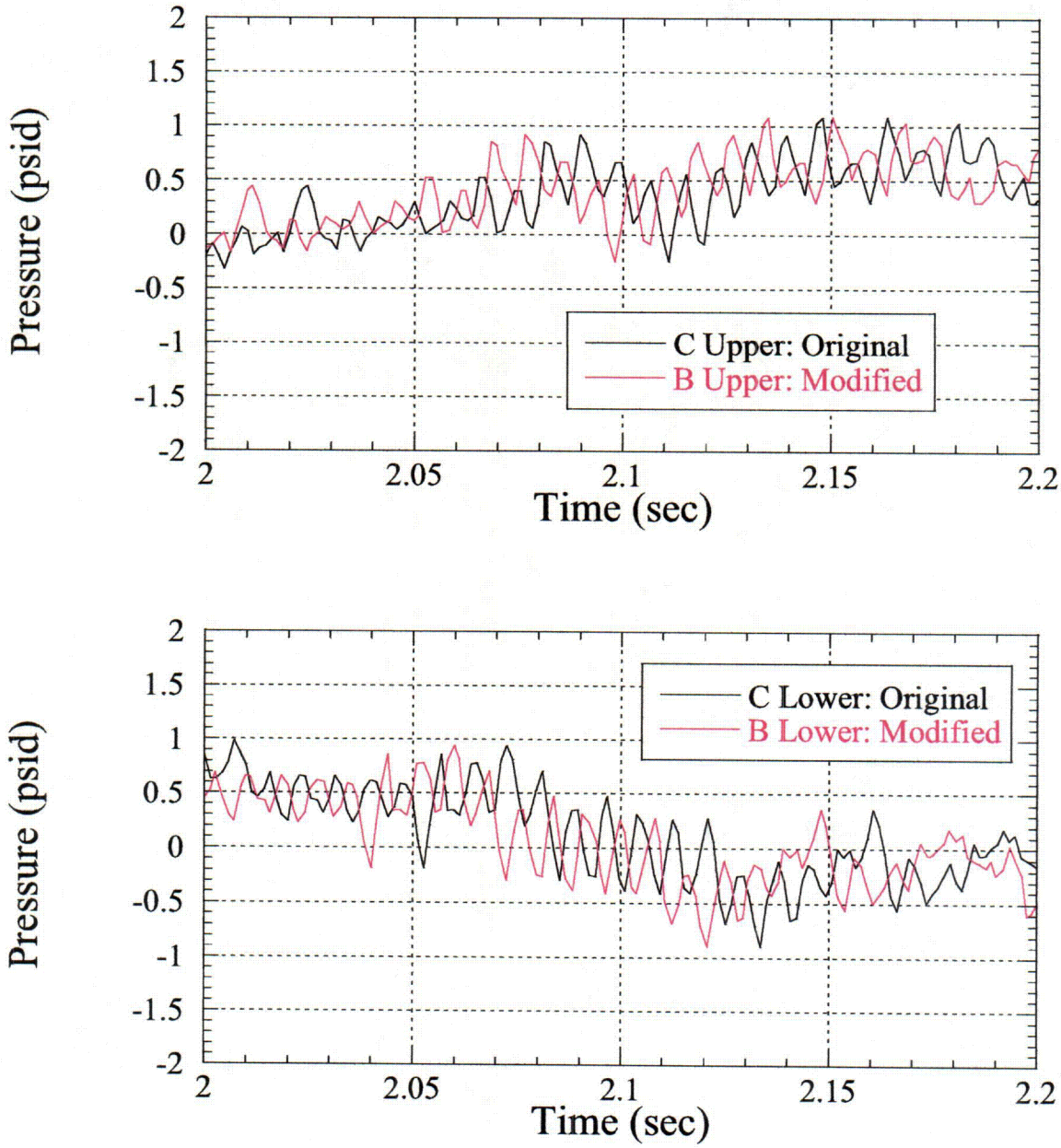
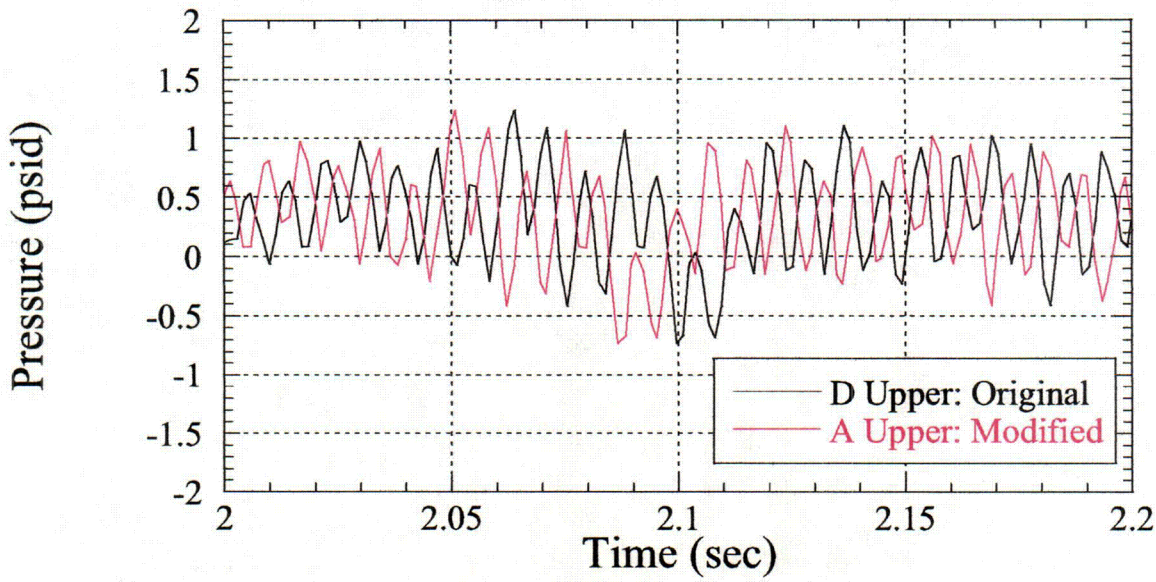


Figure 3. The measured (original) time histories on the C main steam line, compared to the modified time histories on the B main steam line after phase-shifting. The original strain gage data are shown in black, while the modified strain gage data (phase-shifting the C main steam line data) are shown in red. Nine time increments have moved the modified signals 0.0128 seconds back in time in these figures.



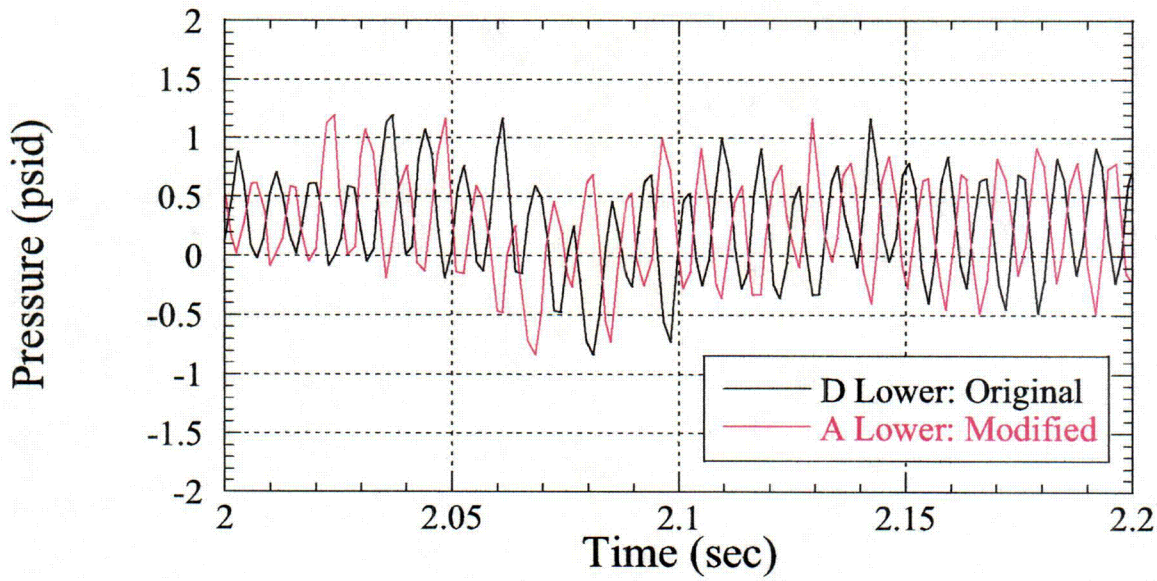


Figure 3 (continued). The measured (original) time histories on the D main steam line, compared to the modified time histories on the A main steam line after phase-shifting. The original strain gage data are shown in black, while the modified strain gage data (phase-shifting the D main steam line data) are shown in red. Nine time increments have moved the modified signals 0.0128 seconds back in time in these figures.

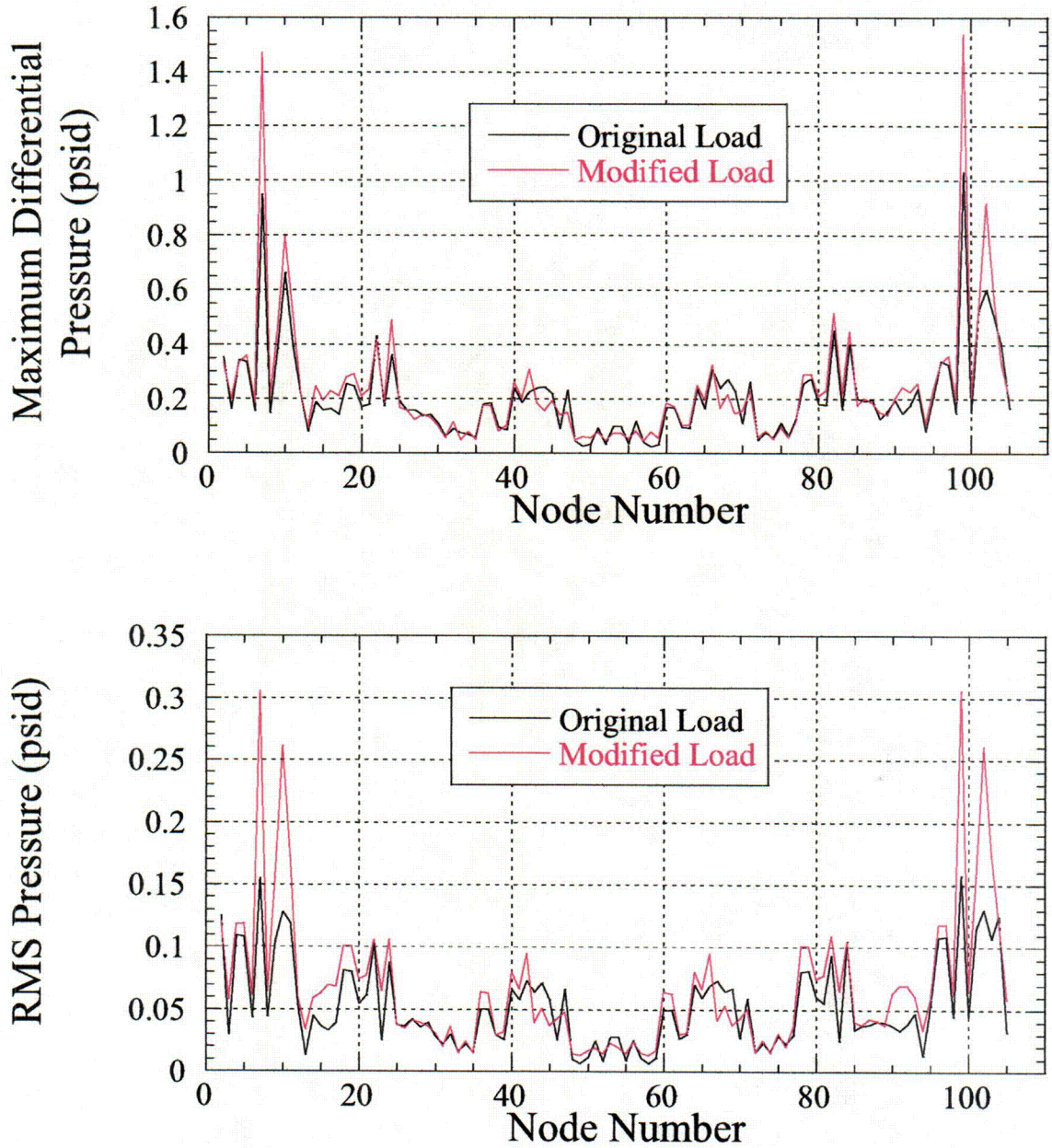


Figure 4. Predicted loads at CLTP power as developed by the current methodology to 200 Hz, based on subscale test results for both the original load and the modified load (phase-shifting the C and D main steam line data placed on the B and A main steam lines, respectively). Node 7 is located at the back center edge of the cover plate opposite the C and D main steam lines, while node 99 is located at the back center edge of the cover plate opposite the A and B main steam lines.

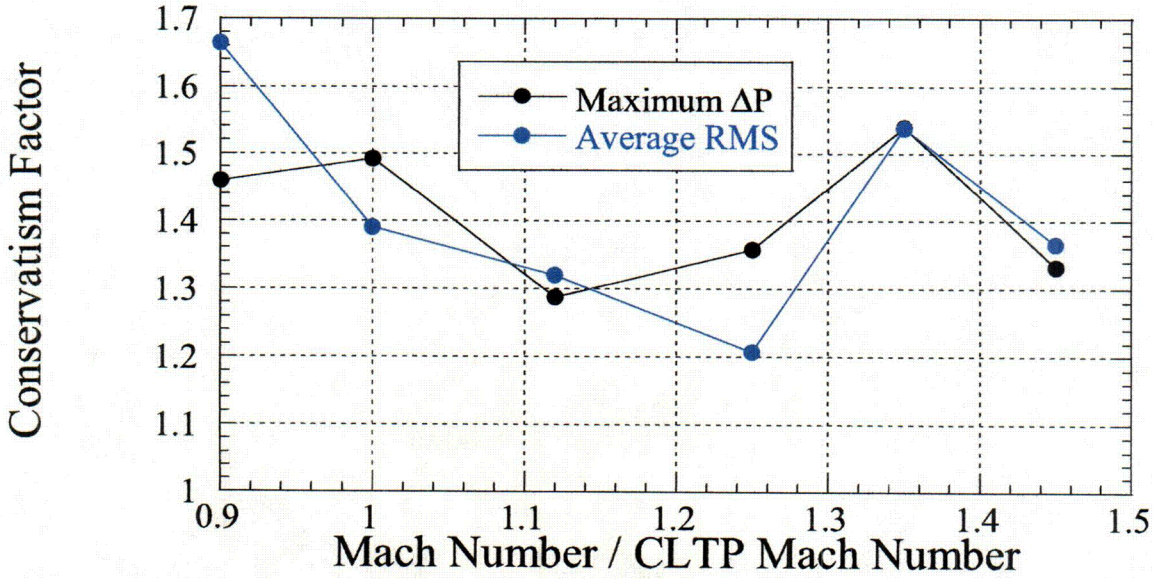


Figure 5. Conservatism factor as determined across the examined Mach number range, for both the maximum differential pressure ΔP (black curve) and the average RMS across the low resolution nodes on the HC1 dryer (blue curve) as shown in Figure 4. The average conservatism factor for both ΔP and RMS is 1.41.