ENCLOSURE 9

WESTINGHOUSE REPORT, WCAP-17548-NP, REVISION 0
SIGNAL PROCESSING PERFORMED ON MONTICELLO MSL STRAIN GAGE AND RSD INSTRUMENTATION DATA

58 pages follow

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Signal Processing Performed on Monticello MSL Strain Gauge and RSD Instrumentation Data

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Executive Summary

Monticello Nuclear generating plant (MNGP, herein referred to as "Monticello") is implementing an extended power uprate (EPU) to increase plant power to [

]a,c

[

]a,c

[

]a,c

[

]a,c

[

]a,c

List of Acronyms and Abbreviations

AC	alternating current
ACE	acoustic circuit enhanced
BWR	boiling water reactor
CDI	Continuum Dynamics, Inc.
CLTP	current licensed thermal power
DAS	data acquisition system
DS	Downstream (used only in figures and tables)
EIC	electrical interference check
EPU	extended power uprate
GE	General Electric
MNGP	Monticello Nuclear Generating Plant
MSL	main steam line
NRC	Nuclear Regulatory Commission
OEM	original equipment manufacturer
PCF	pressure conversion factor
PSD	power spectral density
RMS	root mean square
RPV	reactor pressure vessel
RRP	reactor recirculation pump
RSD	replacement steam dryer
SIA	Structural Integrity Associates
SNR	signal to noise ratio
SRV	safety relief valve
STFT	short time Fourier transform
SURE	Stein's unbiased risk estimator
US	Upstream (used only in figures and tables)

Trademark Notes

VersaDAS is a registered trademark of Structural Integrity Associates

1 BACKGROUND AND INTRODUCTION

1.1 BACKGROUND OF ACOUSTIC ISSUES AND REQUIREMENTS

[

]a,c

NRC Regulatory Guide 1.20, Rev. 3 [1], contains requirements for demonstrating the structural integrity of the steam dryer at power levels higher than CLTP. [

]a,c

1.2 REPLACEMENT OF THE STEAM DRYER

[

][a,b,c]

a,c

Figure 1-1 Schematic of Replacement Steam Dryer

[

][a,b,c]

[

][a,b,c]

1.3 PURPOSE

This report details the signal processing methods used for processing MSL strain gauge data, and the RSD instrumentation data gathered to support the benchmarking of the Acoustic Circuit Enhanced (ACE) technique used to qualify the steam dryer for acoustic loads at EPU operating conditions. To this end, a summary of the data collection and recorded data at Monticello are contained in this document. Furthermore, specific datasets are shown and discussed in detail with regard to the signal processing performed. The intention of presenting this data is to demonstrate the effect, and support the use, of the signal processing described herein.

2 SUMMARY OF PREVIOUS WORK

2.1 ACOUSTIC SCREENING

[

]a,b,c

2.2 SUBSCALE TESTING

[

]a,c

[

]a,b,c

Table 2-1 Natural Frequency of [ ]b					
Side Branch	Natural Frequencies				
	Predicted [3]		[ ]a,c		Plant [5]
	Freq., Hz	Difference	Freq., Hz	Difference	Freq., Hz
[					] b

2.3 PREVIOUS DATA RECORDINGS

[ ]a,c

[

]a,b,c

[

]a,b,c

2.4 DERIVATION OF INSTRUMENTATION LOCATIONS

[

]a,c

a,c

Figure 2-1 Schematic of MSL [ ]a,b,c

[

]a,c

Table 2-2 [
]a,c

MSL	Location	Position

a,b,c

[

]a,c

[

]a,c

a,b,c

Figure 2-2 Schematic of [ ]a,b,c

Figure 2-3 through Figure 2-5 show schematic views of the RSD with the strain gauge locations indicated. The view angle is looking slightly down from above and outside the dryer, similar to the view in the overall dryer schematic seen in Figure 1-1.

a,b,c

Figure 2-3 Schematic of [ ]^{a,b,c}

a,b,c

Figure 2-4 Schematic of [ ]^{a,b,c}

[ ]a,b,c

Figure 2-5 Schematic of [ ]a,b,c

[ ]a,b,c

[ ]a,b,c

Figure 2-6 [ ]a,b,c

[ ]a,b,c

Figure 2-7 Schematic of [ ]a,b,c

[

]a,c

3 DATA COLLECTION AND PROCESSING PLAN

The following sections detail the data collection and processing performed on the recorded time histories from Monticello. The processing documented in this report was applied to the full range of Monticello data in [5] and [8].

3.1 DATA ACQUISITION AND SIGNAL VALIDITY

[

]a,c

[

]a,c

Table 3-1 [ ]a,c

a,c

[ ]a,c

Table 3-2 [ ]a,c

a,c

[ ]a,c

Table 3-3 [ ]a,c

a,c

[ ]a,c

Table 3-4 [ ]a,c

a,c

[

]a,b,c

[

]a,b,c

3.2 DATA PROCESSING OVERVIEW

[

]a,b,c

3.3 STRAIN TO PRESSURE CONVERSION – MSL STRAIN GAUGE DATA

[

]^{a,c}

[ ]^{a,c} (3-1)

where,

[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}

a,c

Figure 3-1 Pipe Mode Diagram, N=[0,5]

[

]a,c

(3-2)

$$\left[\qquad \right]^{a,c}$$

where,

[
]a,c

[
]a,c

[ ]a,c

[
]a,c

3.4 NARROW BAND FILTERING

[
]a,c

[
]a,c

3.5 PSD DERIVATION

The PSDs used in the methods presented in this report were derived using Welch's modified periodogram method. The signal was divided up into time ensembles with the same number of lines as the sampling frequency, resulting in a 1-Hz frequency resolution in the final PSD. A Hanning window was used to reduce spectral leakage, and 50 percent overlap was used in order to increase the number of ensembles available for averaging.

3.6 EIC SUBTRACTION

[

]a,c

[

]a,c

(3-3)

[ ] a,c

where,

[ ]a,c

[ ]a,c

[

]a,c

[ ]a,c (3-4)

where,

[ ]a,c

[ ]a,c

[ ]a,c

The PSDs were derived using Welch's Modified Periodogram method, as described in Section 3.5 [

]a,c

3.7 WAVELET DE-NOISING

[

]a,c

[

]a,c

[

]a,c

[ ]c

1. [ ]c
2. [ ]c
3. [ ]c

[

]^c

[

]^c

[

]^c

4 INPUTS TO SIGNAL PROCESSING AND ASSUMPTIONS

4.1 INPUTS

[

]a,c

[

]a,c

4.2 ASSUMPTIONS

[

]c

[

]c

The acoustic speed in steam is assumed to be 1600 ft/s [12].

[

]a,c

[

]a,c

[

]a,c

[

]a,c

5 DISCUSSION OF RESULTS

5.1 DATA RECORDING

[

]a,c

Table 5-1 Transducers and Units	
Transducer	Units

a,c

[

]a,c

[

]a,b,c

Table 5-2 Dates and Times of Data Recording

Recording	% CLTP	Filename	Date	Time

b

[

]a,c

1.) [

]a,c

2.) [

]a,c

3.) [

]a,c

[

]a,c

[

]a,c

a,c

Figure 5-1 Examples of Transients in Data

[

]^{a,b,c}

[

]^{a,b,c}

5.2 STRAIN TO PRESSURE CONVERSION

[

]^{a,c}

[

]^{a,c}

Table 5-3 [ ]^{a,c}						
MSL	LOC	Channel 1	Channel 2	Channel 3	Channel 4	Mean

b

Table 5-4 shows a summary of the removed channels for each of the MSL strain gauge files.

Table 5-4 [ ]a,c				
Recording	**% CLTP**	**Date Stamp**	**Time Selection**	**Removed Channels**

b

[

]a,c

[

]a,b,c

a,b,c

Figure 5-2 MSL [ ]b,c

[

]a,b,c

a,b,c

Figure 5-3 [ ]b,c

[

]a,b,c

[

]a,b,c

[

]a,b,c

a,b,c

Figure 5-4 [ ]b,c

[

]a,b,c

[

]a,b,c

a,b,c

Figure 5-5 [ ][b,c]

a,b,c

Figure 5-6 [ ][b,c]

[ ][a,b,c]

a,b,c

Figure 5-7 [ ]b,c

[

]a,b,c

5.3 FILTERING

[

]a,c

Table 5-5 Summary of Narrow Band Filters

% CLTP	Date Stamp	Mean Filtering	Electric	Electric x 3	Vane Passing	

b

[

]a,b,c

[ ]b

Figure 5-8 [ ]b,c

[ ]a,b,c

5.4 EIC SUBTRACTION WITH DERIVED MSL PRESSURES

[

]a,b,c

b

Figure 5-9 [

]b,c

[

]a,b,c

[

]^{a,c}

a,b,c

Figure 5-10 [

]^{b,c}

5.5 WAVELET DE-NOISING

[

][a,b,c]

[

][c]

Figure 5-11 [ ][c]

[

][a,b,c]

[

][a,b,c]

[ ][c] (5-1)

where,

[ ][c]
[ ][c]
[ ][c]
[ ][c]

[

][a,b,c]

a,b,c

Figure 5-12 [ ]a,c

[

]a,b,c

[

]a,b,c

[

]c

a,b,c

Figure 5-13 Examples of Cleaned Plant Data Derived MSL Pressures, 100% CLTP

[

]^{c}

a,b,c

Figure 5-14 Comparison of Raw and Processed Data Derived MSL Pressures, 100% CLTP

[

]c

a,b,c

Figure 5-15 Attenuation of MSL Data Due to Processing

[

]a,b,c

[

]a,b,c

a,b,c

Figure 5-16 Complete and Final Processed Data Derived MSL Pressures, 100% CLTP

[

]c

a,b,c

Figure 5-17 [ ]b,c

[

]a,b,c

a,b,c

Figure 5-18 [

]b,c

[

]a,b,c

[

]c

a,b,c

Figure 5-19 [

]b,c

a,b,c

Figure 5-20 [

]b,c

a,b,c

Figure 5-21 [

]b,c

[

]b

[Figure 5-
21

]c

a,b,c

Figure 5-22 [ ]b,c

[

]b,c

[

][c]

a,b,c

Figure 5-23 [

][b,c]

[ ] a,b,c

Figure 5-24 [

]b,c

[ ] a,b,c

Figure 5-25 [

]b,c

a,b,c

Figure 5-26 [

]b,c

a,b,c

Figure 5-27 [

]b,c

[

]a,b,c

[
]c

a,b,c

Figure 5-28 [ ]^{b,c}

6 CONCLUSIONS

[

]a,b,c

The processing steps that define this methodology and that are described in this document can be summarized as follows:

1.) [ ]a,c
2.) [ ]a,c
3.) [ ]a,c
4.) [ ]a,c
5.) [ ]a,c

The resulting datasets are the best available representation of the actual plant data with minimal signature influence from background and noise contributions.

[

]a,b,c

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2. [ ][a,c]

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7. [ ][a,c]

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]a,c

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