<u>ENCLOSURE</u>

ATTACHMENT 13.9

SIA calculation NMP-26Q-302 (Non-proprietary version)

Nine Mile Point Unit 2 Main Steam Line Strain Gage Data Reduction

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Nine Mile Point Nuclear Station, LLC
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CALCULATION PACKAGE

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1.0 INTRODUCTION

During the fall 2007 Nine Mile Point Unit 2 maintenance outage, strain gages were installed on the main steam piping inside the drywell to indirectly measure the dynamic pressure pulsations that occur during plant operation. Main Steam (MS) line strain measurements were recorded during the April 2008 power ascension. The purpose of this calculation is to determine magnitude of pressure pulsation and convert the time history strain gage data into frequency spectra in order to characterize its frequency content. Conversion factors between strain and pressure are also provided for each data location [2].

2.0 TECHNICAL APPROACH

2.1 Data Acquisition Parameters and Filename Convention

The strain gage data [3] was recorded on Structural Integrity's VersaDAS™ Version 4.4 strain gage data acquisition system with each strain gage configuration in a ½ bridge. Each data set was recorded using a sample rate of 2500 samples per second (sps) for 120 seconds.

Each data set contains 32 columns of data in binary format where each column represents 1 channel of ½ bridge MS strain gage data. The channel number versus MS strain gage location is summarized in Table 1. In addition, signals from the individual channels are also grouped into 8 virtual channels based on their location. The purpose of the virtual channels is to calculate the dynamic pressure at a certain pipe location by averaging all working strain gages at that location. Table 3 describes how the recorder channels are combined into virtual channels for each MS gage locations.

Data was obtained during the April 2008 power ascension at 0%, 25%, 45%, 53.5%, 69%, 88%, 90%, 94%, 97% and 100% power levels. The 0% power data set represents reactor conditions low core and no steam flow: Normal Operating Pressure and Normal Operating Temperature (NOP/NOT). Additionally, at every power level above NOP/NOT a measurement was repeated without Wheatstone bridge excitation voltage. In this configuration the cables of the strain gages serve as antennae capturing only the electric noise normally present in the signal. The purpose of this measurement is to identify the noise characteristic of the system. This technique is called Electric Interference Check (EIC). Table 2 summarizes the filenames for each dataset.

Once acquired, these signals were downloaded from the VersaDAS™ data acquisition computer by Structural Integrity Associates (SIA) for analysis. The analysis of the data was done using MATLAB [1].

Table 1: Strain Gage Channels and Locations

Channel No.	MSL	Elevation	Gage	Orientation (Deg)	Comment
1	A	Upper 315' 9-7/8"	01A	0	
			05A	180	
2			02A	45	
			06A	225	
3			03A	90	
			07A	270	
4			04A	135	Inoperational Strain Gage Staring at 0% Power
			08A	315	Inoperational Strain Gage Staring at 0% Power
5		Lower 303' 2-7/16"	09A	0	Inoperational Strain Gage Starting at 0% Power
			13A	180	
6			10A	45	
			14A	225	
7			11A	90	
			15A	270	
8			12A	135	Inoperational Strain Gage Starting at 0% Power
			16A	315	
9	B	Upper 314' 10-5/16"	01B	0	
			05B	180	
10			02B	45	
			06B	225	
11			03B	90	Inoperational Strain Gage Starting at 0% Power
			07B	270	
12			04B	135	Inoperational Strain Gage Starting at 0% Power
			08B	315	
13		Lower 309' 6"	09B	0	
			13B	180	
14			10B	45	
			14B	225	Inoperational Strain Gage Starting at 0% Power
15			11B	90	
			15B	270	
16			12B	135	
			16B	315	
17	C	Upper 307' 3-5/16"	01C	0	
			05C	180	Inoperational Strain Gage Starting at 0% Power
18			02C	45	Inoperational Strain Gage Starting at 0% Power
			06C	225	
19			03C	90	
			07C	270	
20			04C	135	Inoperational Strain Gage Starting at 0% Power
			08C	315	
21		Lower 301' 11"	09C	0	
			13C	180	
22			10C	45	
			14C	225	
23			11C	90	
			15C	270	
24			12C	135	
			16C	315	
25	D	Upper 309'	01D	0	
			05D	180	Inoperational Strain Gage Starting at 0% Power
26			02D	45	
			06D	225	
27			03D	90	
			07D	270	
28			04D	135	Inoperational Strain Gage Starting at 0% Power
			08D	315	Inoperational Strain Gage Starting at 0% Power
29		Lower 303' 7-11/16"	09D	0	
			13D	180	
30			10D	45	
			14D	225	
31			11D	90	Inoperational Strain Gage Starting at 0% Power
			15D	270	
32			12D	135	
			16D	315	

Table 2: File Names vs. Power Levels

Data Files					
Power %		File Name	Date	Time	Comment
NOP/NOT	DATA	20080416224519.dta	4/16/2008	22:45	No EIC
	EIC	-	-	-	
25	DATA	20080417082119.dta	4/17/2008	8:21:00 AM	
	EIC	20080417082921.dta	4/17/2008	8:29:00 AM	
45	DATA	20080418064142.dta	4/18/2008	6:41	
	EIC	20080418063619.dta	4/18/2008	6:36	
53.5	DATA	20080418102812.dta	4/18/2008	10:28:00 AM	One FW Pump
	EIC	20080418103314.dta	4/18/2008	10:33:00 AM	
53.5	DATA	20080418114515.dta	4/18/2008	11:45:00 AM	Two FW Pumps
	EIC	20080418115050.dta	4/18/2008	11:50:00 AM	
69	DATA	20080418133533.dta	4/18/2008	1:35:00 PM	
	EIC	20080418134134.dta	4/18/2008	1:41:00 PM	
88	DATA	20080419042237.dta	4/19/2008	4:22:00 AM	
	EIC	20080419042836.dta	4/19/2008	4:28:00 AM	
90	DATA	20080419052320.dta	4/19/2008	5:23:00 AM	
	EIC	20080419051618.dta	4/19/2008	5:16:00 AM	
94	DATA	20080419070235.dta	4/19/2008	7:02:00 AM	
	EIC	20080419065611.dta	4/19/2008	6:56:00 AM	
97	DATA	20080419082350.dta	4/19/2008	8:23:00 AM	
	EIC	20080419081737.dta	4/19/2008	8:17:00 AM	
100	DATA	20080419094734.dta	4/19/2008	9:47:00 AM	
	EIC	20080419094134.dta	4/19/2008	9:41:00 AM	

Table 3: Virtual Channels

Location	Channels
MSL-A-Upper	1 2 3
MSL-A-Lower	5 6 7 8
MSL-B-Upper	9 10 11 12
MSL-B-Lower	13 14 15 16
MSL-C-Upper	17 18 19 20
MSL-C-Lower	21 22 23 24
MSL-D-Upper	25 26 27
MSL-D-Lower	29 30 31 32

2.2 Channels with Invalid Signals

Initial review of the main steam line strain gage data was performed to determine if the data was valid and to determine how to combine the strain gage data at each MS line location. Based on this review certain channels have failed and these signals were not used in any of the subsequent analyses. On channels 4 and 28, both strain gages, had bad resistance reading starting at 0% power level. The Wheatstone bridge on these channels could not be balanced and had to be excluded from the entire data processing. A couple of strain gages failed prior the power ascension (Table 1) and their functioning condition did not change during the entire power ascension. Table 3 summarizes the created virtual channels for the power ascension as well as the channel exclusions.

2.3 Data Reduction Methodology

2.4 Strain Gage Data and Dynamic Pressure Estimates

The strain gages to Pressure Conversion Factors (PCF) were determined using formulas for a thick wall cylinder acted upon by internal pressure only Reference [2]. Table 5 summarizes the pressure conversion factors for each main steam line location.

Table 5: Pressure Conversion Factor

Channel No.	MSL	Elevation	Mean Conversion Factor for each location (psi/με)
1	A	Upper 315' 9-7/8"	3.82
2			
3			
4			
5		Lower 303' 2-7/16"	3.84
6			
7			
8			
9	B	Upper 314' 10-5/16"	3.84
10			
11			
12			
13		Lower 309' 6"	3.81
14			
15			
16			
17	C	Upper 307' 3-5/16"	3.85
18			
19			
20			
21		Lower 301' 11"	3.81
22			
23			
24			
25	D	Upper 309'	3.92
26			
27			
28			
29		Lower 303' 7-11/16"	3.94
30			
31			
32			

3.0 STRAIN GAGE INSTRUMENT LOCATIONS

Eight sets of strain gages were installed at eight elevations on the main steam piping inside the drywell with 2 locations per line. The opposite strain gages are connected in a ½ bridge in order to reduce the effect of the bending modes. These eight groups of strain gages were combined into eight virtual channels. Table 3 shows the detailed description of these 8 virtual channels.
In order to increase the quality of the signal an External Power Source (EPS) was used to provide more robust voltage excitation to the Wheatstone bridges. The application of the EPS made the EIC measurement relatively easy. That is the reason why all the data sets above NOP/NOT level are coupled with an EIC data set.

At 100% power level a coherence check was done to verify the improved signal quality. For every main steam line, the upper and the lower virtual channels were coupled to check the coherence level. These plots are shown in Figure 11 thought Figure 14. The upper and lower virtual channels are mechanically coupled. The excitation induced by the acoustic pressure pulsation, in the common space, results that the coherence is reaching higher values in lower frequency domain. Figure 15 shows the coherence plot of two virtual channels where the source (acoustic pressure pulsation) and the mechanical path have highly indirect relationship and coupling. The coherence check, between MSL-A-Upper and MSL-B-Upper, results in generally low coherence.

It is important to notice that on the coherence plots there are a couple of peaks reaching near 1 value. These peaks are the result of electrical interference of 60Hz and its upper harmonics (common excitation of changing external magnetic and electrostatic filed). Also we can observe high coherence at 149Hz. At this frequency the coherence is high because all the strain gages have a response due to the uniform mechanical vane pass excitation.

4.0 VIBRATION DATA

Appendices A through K contain the frequency spectra for the strain gage vibration data collected during the April 2008 power ascension. Vibration data for all ten (10) power levels were recorded and the corresponding frequency spectra were generated using MATLAB [1].

Appendix	A	–	0%	Power
Appendix	B	–	25%	Power
Appendix	C	–	45%	Power
Appendix	D	–	53.5%	Power
Appendix	E	–	53.5%	Power
Appendix	F	–	69%	Power
Appendix	G	–	88%	Power
Appendix	H	–	90%	Power
Appendix	I	–	94%	Power
Appendix	J	–	97%	Power
Appendix	K	–	100%	Power
Appendix	L	–	Waterfall Plots	

Table 8 through Table 16 contain summaries of the strain RMS and Max-Min values (με) and corresponding pressure values (psi) for each power level.

Figure 1 through Figure 10 show the RMS micro strain values as a function of power level for each MS lines and elevations. In addition, waterfall plots are provided in Appendix L of the frequency spectra versus power level for each of the combined main steam line strain gage data sets.

4.1 Noise floor comparison

Additional tests were performed in order to compare the NMP noise floor to the laboratory noise floor test. The NMP noise floor was captured generating EICs at different power levels. These EIC noise floors combine the noise originated from the signal path such as cabling and penetration plus the noise of the data acquisition hardware itself.

The laboratory noise floor was generated using 300ft cables with two real strain gages with identical data acquisition hardware. For the lab test the two strain gages connected in similar fashion to a half bridge like the strain gages on the NMP main steam lines.

The EICs recorded at 25% and 100% power level and the EIC generated in laboratory environment are nearly identical showing that the NMP has excellent installation of strain gage data acquisition system. However, when laboratory generated noise floor is compared to that of real data at 25% and 100% of power, it is apparent that the lab noise floor is lower at all frequencies and it never obscures any strain signals. Therefore, it is safe to filter any electrical and mechanical interference frequencies present in the EIC recordings out of the actual strain data. The results of these comparisons can be seen on Figure 16 and Figure 17.

5.0 SUMMARY

Main steam strain gage data was collected following the April 2008 Nine Mile Point Unit 2 maintenance outage. Initially the gages were connected in ½ Wheatstone bridge with two strain gages at the opposite side of the main steam pipe. When one of the strain gages failed it was replaced by a completion resistor and the ½ bridge was configure to a ¼ bridge.
The data was collected at ten (10) power levels during the power ascension. At every power level above NOP/NOT an extra set of data was recorded without bridge excitation in order to identify the characteristic of the electric noise in the signal. During the data acquisition an analog filter was used to prevent signal aliasing. When the data was post processed different types of digital filter were applied to remove undesired frequency content originated from 60Hz AC electrical network and the Reactor Recirculation System pumps.

Observations:

1) In general the maximum time history RMS micro-strain of the virtual channels is less than 0.17. The highest RMS micro-strain of 0.16274 is measured on MSL-C-Upper at 100% power level.

2) In the frequency spectra the dominant frequencies are lower than 50Hz.

3) 60Hz electrical noise and its upper harmonics in the signal were expected based on industrial experience. The presence of this electrical noise and the correct application of notch filters, to remove these frequencies, were verified by the Electrical Interference Check at different power level.

4) Coherence check at 100% has satisfying results.

5) In general the noise floor is between 1 and 2 nano-strain.

6.0 REFERENCES

1. MATLAB, Version 7.1.0.246, Release 14, Service Pack 3, Mathworks, August 02, 2005.

2. Structural Integrity Associates Calculation, "Nine Mile Point Unit 2 Strain Gage Uncertainty Evaluation and Pressure Conversion Factors", Revision 0, SI File No. NMP-26Q-301.

3. Nine Mile Point Unit 2 April 2008 Strain Gage Data, SI File NMP-26Q-209.

All content in Appendices A through L are proprietary and are excluded from this version of the document.