Attachment 45

Flow Induced Vibration Analysis and Monitoring Program

1.0 INTRODUCTION

This Attachment to the submittal provides a detailed discussion of the analyses and testing program undertaken to provide assurance that unacceptable flow induced vibration (FIV) issues are not experienced at Browns Ferry Nuclear Plant (BFN) due to extended power uprate (EPU) implementation for affected piping systems.

Increased flow rates and flow velocities during operation at EPU conditions are expected to produce increased FIV levels in some systems. As discussed in Section 3.4.1 of Licensing Topical Report (LTR) NEDC-33004P-A, Revision 4, “Constant Pressure Power Uprate,” the Main Steam (MS) and Feedwater (FW) system piping vibration levels should be monitored because their system flow rates will be significantly increased (Reference 1).

In December 2008, the Boiling Water Reactor Owners’ Group (BWROG) issued NEDO-33159, Revision 2, “Extended Power Uprate (EPU) Lessons Learned and Recommendations,” based on operating experience (OE) and evaluations from Boiling Water Reactor (BWR) plants that have previously implemented EPUs and from plants currently performing pre-EPU evaluations. NEDO-33159 (Reference 2) states:

> “Since the majority of EPU-related component failures involve flow induced vibration, the BWROG EPU Committee held a vibration monitoring and evaluation information exchange meeting of industry experts in June 2004. The committee determined with the current process of monitoring large bore piping systems in accordance with the requirements of ASMEO&M Part 3 is sufficient to preclude challenges to safe shutdown. Increases in large bore piping vibration levels are a precursor to increased vibration levels in attached small bore piping and components.”

Regulatory Guide (RG) 1.20 (Reference 3), “Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing,” was revised in 2007 to Revision 3. In addition to guidance for vibration assessment of reactor internals, this regulatory guide provides helpful information on methods for evaluating the potential adverse effects from pressure fluctuations and vibrations in piping systems for boiling water reactor (BWR) nuclear power plants. However, additional guidance is provided with regard to piping vibration. The guidance is primarily directed to initial start-up of new plants, with general guidance interpreted for use in power uprate power ascension testing. Where applicable, this guidance has been incorporated into the EPU monitoring program for piping vibration at BFN.

In addition to MS and FW, the related Extraction Steam (ES), Condensate (CD) and Heater Drain (HD) systems also experience similar flow increases under EPU conditions and are included in the EPU vibration monitoring program. Other systems experience insignificant or no increase in flow and; therefore, are not included in this program.

Review of power ascension vibration data collected during initial restart of BFN Unit 1 indicates vibration levels well within acceptable limits at current licensed thermal power (CLTP). Extrapolation of this earlier data to EPU power levels indicates that vibration of piping and components will not be adversely affected by EPU operation.

This document describes the piping vibration monitoring program to be implemented at TVA during power ascension to confirm acceptable vibration levels at EPU power. It compares previously collected vibration data to conservative projections for EPU vibration levels based on increases in vibration being proportional to increases in flow rate squared. It addresses systems impacted by EPU and identifies locations on those systems where monitoring equipment will be installed. This document also describes the techniques to be used for collecting and storing the vibration data.

2.0 SUSCEPTIBILITY AND MONITORING

The MS and FW piping will experience higher mass flow rates and flow velocities under EPU conditions. When power is increased, steady state FIV levels are conservatively expected to increase in proportion to the flow velocity squared. Thus, the vibration levels of the MS and FW piping are expected to increase by approximately 35% from CLTP to EPU conditions and 58.5% from OLTP to EPU conditions, based on flow increases of up to 16% for CLTP and 23% for OLTP. Other possible sources of increased vibration, such as flow instabilities or acoustic resonance as a result of increased flow velocities, may contribute to EPU vibration levels. It is noted that acoustic vibration suppressors have been installed on the MS system at BFN to reduce vibration susceptibility of piping and components.

Flow rates in portions of the CD, ES and HD systems increase similarly to MS and FW, and are, therefore, susceptible to increased vibration at EPU conditions.

Based on the potential for significantly increased vibrations on the systems identified above, a confirmatory test program will be implemented to monitor piping and attached component vibration levels on the identified systems during initial power ascension to EPU conditions. The test program will incorporate the guidance and OE discussed in Section 1.0, industry experience from recently implemented EPU FIV monitoring programs and other industry OE related to FIV issues experienced in piping and attached components.

Piping inside containment and inaccessible piping outside containment will be monitored using vibration sensors (accelerometers or displacement transducers) installed at selected locations on the piping and attached components. The vibration sensors will be wired to remote data acquisition systems located in the reactor and turbine buildings. Piping outside containment that is included in the monitoring program and is accessible during plant operation will be monitored either remotely or by performing visual observations or taking vibration measurements using hand-held vibration instruments during power ascension to EPU conditions.

Small bore branch piping is susceptible to the effects of the associated large bore piping FIV. Modifications to small bore branch piping to reduce susceptibility to header-induced vibrations have been made as a result of BFN operating experience. Small bore piping assessments, supplemented by confirmatory walkdowns, will be performed during the refueling outage prior to the EPU implementation outage for each unit to identify any additional potentially susceptible configurations. Any necessary small bore line modifications will be made prior to EPU power ascension. Selected small bore branch lines will be monitored for vibration during EPU power ascension to confirm that vibrations are within acceptable limits.

3.0 RESULTS FROM PREVIOUS VIBRATION TEST PROGRAMS AND EPU PROJECTS

Vibration levels at CLTP (3458 MWt) were obtained as part of the BFN Unit 1 restart in 2007, with additional CLTP data obtained in 2008, for MS and FW piping and components. The Unit 1 CLTP vibration monitoring results are part of the basis for the vibration monitoring to be performed during EPU power ascension for BFN Units 1, 2 and 3. The Unit 1 baseline vibration monitoring results are used to demonstrate that projected vibrations are anticipated to be acceptable. This conclusion is applicable to the other units based on the general similarity of the three units. For the analyses performed to determine monitoring locations and acceptance criteria, the unit specific piping and support configurations are taken into account.

The MS and FW monitoring locations included in the 2007 and 2008 monitoring scope are summarized below:

<u>Inside Containment</u>

MS Piping: 7 monitoring locations, 12 measurements (1 or 2 directions per location)

FW Piping: 9 monitoring locations, 14 measurements (1 or 2 directions per location)

MS Components: 8 monitoring locations, 24 measurements (3 directions per location)

<u>Outside Containment</u>

MS piping: 11 monitoring locations, 20 measurements (1 to 3 directions per location)

FW piping: 13 monitoring locations, 23 measurements (1 or 2 directions per location)

The CLTP measured vibration levels, projected EPU vibration levels and comparisons of EPU projections with acceptance criteria are summarized in Tables 3-1 through 3-4 of this attachment. The projected EPU vibration levels are calculated using the following equation:

$$\text{EPU vibration level} = (\text{CLTP vibration level}) * (\text{EPU flow rate} / \text{CLTP flow rate})^2$$

The acceptance criteria were developed using the methodology described in Section 4.2.

The results presented in Tables 3-1 through 3-4 of this attachment illustrate the acceptability of previously-measured vibrations. Based on conservative projections, vibrations at EPU conditions are expected to remain within acceptable limits.

Table 3-1
CLTP Results and EPU Projections for Piping Monitoring Locations Inside Containment

System	Piping Identifier	Monitoring Location-Direction	CLTP Measured Vibration (Note 1)	EPU Projected Vibration (Note 1)	Acceptance Criteria (Note 1)	Projected % of Acceptance Criteria
MS	MS Line B	A3A-T	15	20	67	30
		A3A-R	10	14	55	25
MS	MS Line A	15-T	14	19	100	19
		15-R	7	9	100	9
MS	MS Line C	246-T	12	16	25	64
		246-R	18	24	40	60
MS	MS Ring H	85-R	3	4	84	5
		85-Y	15	20	84	24
MS	MS Line B	19A-Y	2	3	98	3
MS	MS Line C	40-X	5	7	31	23
		40-Z	2	3	61	5
MS	MS Line C	36,37-Y	5	7	106	7
FW	FW Nozzle B	BT-X	0.27	0.36	2.71	13
		BT-Z	0.17	0.23	1.53	15
FW	FW Nozzle C	16-R	0.28	0.38	2.23	17
		16-T	0.15	0.2	0.93	22
FW	FW Nozzle A	ATA-R	0.2	0.27	3.83	7
FW	FW Ring Header	19A-Y	0.17	0.23	1.77	13
FW	FW Nozzle F	8A-R	0.15	0.2	3.23	6
FW	FW Nozzle E	24A-X	0.25	0.34	1.59	21
		24A-Z	0.16	0.22	5.02	4
FW	FW Ring Header	15D-Y	0.24	0.32	1.31	24
FW	FW Nozzle D	42A-R	0.37	0.5	3.07	16
		42A-T	0.21	0.28	3.05	9
FW	FCV-3-562 FW	55BQ-V	0.42	0.57	0.90	63
		55BQ-T	0.12	0.16	0.47	34

Note 1: Vibration values shown are in terms of displacement (mils pk-pk) for MS and acceleration (g's peak) for FW.

Table 3-2
CLTP Results and EPU Projections for Large Bore Piping Monitoring Locations Outside Containment

System	Piping Identifier	Monitoring Location-Direction	CLTP Measured Vibration (mils pk-pk)	EPU Projected Vibration (mils pk-pk)	Acceptance Criteria (mils pk-pk)	Projected % of Acceptance Criteria
MS	Main Steam Line B 24"	B125-X	42	57	75	76
MS	Main Steam Line D 24"	D125-X	45	61	106	58
MS	Bypass Valves 8" Line	L75-Y	24	32	122	26
		L75-Z	23	31	100	31
MS	Main Steam Line A 28"	A310-Z	79	107	167	64
		A310-X	53	72	87	83
		A310-Y	13	18	80	23
MS	Main Steam Line C 28"	C290-X	31	42	66	64
		C290-Y	2	3	160	2
		C290-Z	44	59	247	24
FW	RFP 1A 18" Discharge	A38-Y	9	12	52	23
		A38-X	7	9	104	9
FW	RFP 1A 18" Discharge	47-Z	16	22	311	7
FW	RFP 1B 18" Discharge	142A-Y	2	3	129	2
		142A-X	2	3	108	3
FW	RFP 1B 18" Discharge	132A-Z	11	15	324	5
FW	RFP 1C 18" Discharge	80A-Y	2	3	129	2
FW	Heater String A2 18" Line	215B-Z	15	20	187	11
		215B-X	4	5	120	4
FW	Heater String A1 18" Line	95A-Y	1	1	33	3
		95A-X	1	1	58	2
FW	Heater String C1 18" Line	32-Y	3	4	37	11
		32-Z	3	4	46	9
FW	RFW 24" Disch Return	135A-X	10	14	45	31
		135A-Z	1	1	48	2

Table 3-3
CLTP Results and EPU Projections for Small Bore Piping Monitoring Locations Outside Containment

System	Piping Identifier	Monitoring Location-Direction	CLTP Measured Vibration (mils pk-pk)	EPU Projected Vibration (mils pk-pk)	Acceptance Criteria (mils pk-pk)	Projected % of Acceptance Criteria
MS	Main Steam Line A 1"[1]	M30-X	139	(1)	(1)	(1)
		M30-Z	97	(1)	(1)	(1)
MS	Main Steam Line C 1"[1]	N30-X	44	(1)	(1)	(1)
		N30-Z	70	(1)	(1)	(1)
MS	Stop Valve 1C	F37-X	37	50	222	23
		F37-Z	11	15	272	6
MS	Control Valve 1A 1" Line	G99-X	62	84	101	83
		G99-Y	4	5	95	5
MS	Control Valve 1C 2.5" Line	G55-Z	3	4	121	3
MS	Control Valve 1D 1" Line	G22-X	11	15	99	15
FW	RFP 1A .5" Discharge	E30/E40-X	4	5	1165	<1
		E30/E40-Z	5	7	555	1
FW	RFP 1A 1" Vent	F20/F40-X	3	4	95	4
		F20/F40-Z	20	27	377	7
FW	RFP 1C 1" Vent	G20/G40-X	4	5	22	23
		G20/G40-Z	29	39	59	66
FW	RFP 1C 1.5" Vent	H31-Z	2	3	41	7
		H31-Y	4	5	102	5

Note 1: Tie-back support installed after CLTP measurements to mitigate header-induced vibration effects.

Table 3-4
CLTP Results and EPU Projections for Main Steam Valve Monitoring Locations

Valve ID	Valve Description	Monitoring Direction	CLTP Measured Vibration (g's rms)	EPU Projected Vibration (g's rms)	Acceptance Criteria (g's rms)	Projected % of Acceptance Criteria
FCV-1-14	MSIV	X	(1)	N/A	0.260	N/A
		Y	(1)	N/A	0.136	N/A
		Z	0.10	0.14	0.386	36
FCV-1-55	MS Drain	X	0.06	0.08	0.166	48
		Y	0.04	0.05	0.214	23
		Z	(1)	N/A	0.157	N/A
FCV-71-2	RCIC	X	0.06	0.08	0.166	48
		Y	0.04	0.05	0.215	23
		Z	0.05	0.07	0.157	45
FCV-73-2	HPCI	X	0.04	0.05	0.374	13
		Y	(1)	N/A	0.234	N/A
		Z	0.06	0.08	0.234	34
PCV-1-4	SRV	X	0.09	0.12	0.69	17
		Y	0.09	0.12	0.90	13
		Z	0.08	0.11	0.40	28
PCV-1-34	SRV	X	0.12	0.16	0.69	23
		Y	0.10	0.14	0.90	16
		Z	0.15	0.2	0.40	50
PCV-1-22	SRV	X	0.08	0.11	0.69	16
		Y	0.11	0.15	0.90	17
		Z	0.05	0.07	0.40	18
PCV-1-180	SRV	X	0.07	0.09	0.69	13
		Y	0.10	0.14	0.90	16
		Z	0.10	0.14	0.40	35

Note 1: Inoperable sensor.

4.0 EPU VIBRATION MONITORING PROGRAM

4.1 Overview

The portions of the MS, FW, CD, HD and ES systems included in the EPU vibration monitoring program have been selected based on evaluation of the flow increases resulting from EPU implementation. The specific EPU vibration monitoring locations and acceptance criteria are established using detailed analysis methods, as described in Section 4.2. The EPU flow increase evaluation and vibration analysis results form the bases for EPU vibration monitoring.

Several MS-associated components will also be monitored. Although BFN does not have a history of safety-relief valve maintenance issues due to vibration, selected safety-relief valves will be instrumented with accelerometers, as well as four other power-operated valves. This is in response to industry OE from an earlier EPU project. A representative sample of valves were selected to monitor the effect of EPU flow changes on the vibration levels at the primary valves in the system with symmetry between trains, loops and units considered to remove unnecessary redundancies.

4.2 Vibration Monitoring Locations and Acceptance Criteria Development

4.2.1 MS and FW Piping (Inside and Outside Containment)

Hydraulic and structural models of the MS and FW piping were created for determination of the vibration monitoring locations and development of the vibration acceptance criteria. The hydraulic analyses were performed to generate piping leg force time histories simulating loading due to dynamic pressure fluctuations that cause piping steady-state vibrations. The generated force time histories were used as input for force time history analyses performed to provide piping structural responses. The intent of the hydraulic and structural dynamic analyses was to apply loading that is similar to the loading due to steady-state vibration, and generate responses that are based on the piping system acoustic and structural properties. Because the exact forcing functions are unknown, the analytical responses are not predicted responses. However, the deflected shape of the piping and the resulting stress distribution will correspond to the appropriate type of loading.

The vibration monitoring locations were selected where, based on the structural time history analysis results, significant displacements occurred relative to other locations. The measurement locations were also selected such that the general overall piping response would be reflected in the data and it would not be likely that significant vibrations would be missed. Where applicable, symmetry between trains or loops was considered to reduce the overall number of monitoring locations. The EPU vibration monitoring locations determined for the MS and FW piping from the analyses are summarized in Tables 4-1 through 4-3 of this attachment.

Allowable displacement (mils pk-pk) and acceleration (g's-pk) limits at the selected measurement locations were calculated based on the analysis results and ASME code fatigue stress limits for steady state vibration consistent with ASME OM-S/G, Part 3 (OM-3)

(Reference 4). The primary acceptance criteria are in terms of displacement, which is directly proportional to pipe stress. Secondary acceptance criteria in terms of acceleration were determined for locations where accelerometers are used for monitoring.

The displacement limits for MS and FW are applicable for vibration frequencies up to 50 Hz, which corresponds to the frequency range in which the most significant structural displacement responses are expected. Piping displacements due to excitation frequencies above 50 Hz are typically insignificant relative to the lower frequency displacements. Secondary acceleration limits established for the FW piping inside containment are also applicable for frequencies up to 50 Hz, since significant forcing frequencies and structural responses above 50 Hz are not expected in the FW system.

Small bore piping attached to the MS and FW piping were reviewed for potential susceptibility to header-induced vibrations. The lines determined to be most susceptible were selected for monitoring and acceptance criteria were developed accordingly. The following factors were considered for the small bore line evaluations:

- The presence or absence of a tie-back support. Tie-back supports are added to reduce the influence of header-induced vibrations on small bore lines. Therefore, lines with tie-back supports are generally not susceptible to header-induced vibrations.
- The routing and support configurations of the small bore lines. Lines with unsupported concentrated masses or long, unsupported runs are generally most susceptible to header-induced vibrations.
- The expected amplitudes of the header vibrations. The more rigidly supported the header piping is in the vicinity of the branch connection, the lower the amplitudes of the header vibrations. The expected relative amplitudes of the header vibrations are checked in the header time history analyses.
- Small bore lines included in the large bore piping models. In these cases, the time history analysis results are used to determine the susceptibility of the small bore lines to the header-induced vibrations.

Table 4-1
EPU Monitoring Locations for MS and FW Piping (Inside Containment)[1]

System	Location	Direction	Description
MS	A3A	T	MS Line B – El. 620.50’
MS	A3A	R	MS Line B – El. 620.50’
MS	15	T	MS Line A – El. 621.00’
MS	15	R	MS Line A – El. 621.00’
MS	246	T	MS Line C – El. 621.00’
MS	246	R	MS Line C – El. 621.00’
MS	85	R	MS Ring H – El. 586.58’
MS	85	Y	MS Ring H – El. 586.58’
MS	19A	Y	MS Line B – El. 578.08’
MS	40	X	MS Line C – El. 575.26’
MS	40	Z	MS Line C – El. 575.26’
MS	36,37	Y	MS Line C – El. 584.33’/578.22’
FW	BT	X	FW Nozzle B – El. 613.41’
FW	BT	Z	FW Nozzle B – El. 613.41’
FW	I6	R	FW Nozzle C – El. 610.00’
FW	I6	T	FW Nozzle C – El. 610.00’
FW	ATA	R	FW Nozzle A – El. 611.32’
FW	19A	Y	FW Ring Header – EL. 587.00’
FW	8A	R	FW Nozzle F – El. 611.55’
FW	24A	X	FW Nozzle E – El. 611.42’
FW	24A	Z	FW Nozzle E – El. 611.42’
FW	15D	Y	FW Ring Header – El. 587.09’
FW	42A	R	FW Nozzle D – El. 611.64’
FW	42A	T	FW Nozzle D – El. 611.64’
FW	55BQ	V	FCV-3-562 FW
FW	55BQ	T	FCV-3-562 FW

Note 1: The specific node numbers and locations listed in Table 4-1 correspond to BFN Unit 1. The equivalent locations in BFN Units 2 and 3, as applicable, will also be monitored.

Table 4-2
EPU Monitoring Locations for MS and FW Large Bore Piping (Outside Containment)[1]

System	Location	Direction	Description
MS	B125	X	MS Line B 24”
MS	D125	X	MS Line D 24”
MS	L75	Y	Bypass Valves 8” Line
MS	L75	Z	Bypass Valves 8” Line
MS	A310	Z	MS Line A 28”
MS	A310	X	MS Line A 28”
MS	A310	Y	MS Line A 28”
MS	C290	X	MS Line C 28”
MS	C290	Y	MS Line C 28”
MS	C290	Z	MS Line C 28”
FW	A38	Y	RFP 1A 18” Disch.
FW	A38	X	RFP 1A 18” Disch
FW	47	Z	RFP 1A 18” Disch.
FW	142A	Y	RFP 1B 18” Disch.
FW	142A	X	RFP 1B 18” Disch.
FW	132A	Z	RFP 1B 18” Disch.
FW	80A	Y	RFP 1C 18” Disch.
FW	215B	Z	Heater String A2 18” Line
FW	215B	X	Heater String A2 18” Line
FW	95A	Y	Heater String A1 18” Line
FW	95A	X	Heater String A1 18” Line
FW	32	Y	Heater String C1 18” Line
FW	32	Z	Heater String C1 18” Line
FW	135A	X	RFW 24” Disch. Return
FW	135A	Z	RFW 24” Disch. Return

Note 1: The specific node numbers and locations listed in Table 4-2 correspond to BFN Unit 1. The equivalent locations in BFN Units 2 and 3, as applicable, will also be monitored.

Table 4-3
EPU Monitoring Locations for MS and FW Small Bore Piping (Outside Containment)[1]

System	Location	Direction	Description
MS	M30	X	Main Steam Line A 1”
		Z	
MS	N30	X	Main Steam Line C 1”
		Z	
MS	F37	X	Stop Valve 1C
		Z	
MS	G99	X	Control Valve 1A 1” Line
		Y	
MS	G55	Z	Control Valve 1C 2.5” Line
MS	G22	X	Control Valve 1D 1” Line
FW	E30/E40	X	RFP 1A .5” Line
		Z	
FW	F20/F40	X	RFP 1A 1” Vent
		Z	
FW	G20/G40	X	RFP 1C 1” Vent
		Z	
FW	H31	Z	RFP 1C 1.5” Vent
		Y	

Note 1: The specific node numbers and locations listed in Table 4-3 correspond to BFN Unit 1. The equivalent locations in BFN Units 2 and 3, as applicable, will also be monitored.

4.2.2 CD, ES and HD Piping (Outside Containment)

Significant flow increases occur in portions of the condensate, extraction steam and heater drain systems as a result of EPU. The portions of the systems selected for monitoring were based on the percent flow increase due to EPU, projected EPU flow rates, a review of the piping configurations and similarities between trains and units. Determination of specific monitoring locations and acceptance criteria will be based on analysis methodologies consistent with ASME OM-3.

Condensate:

The condensate system will experience a flow increase of approximately 16% as a result of EPU. The piping between the 3rd stage feedwater heaters and the reactor feedwater pumps (RFPs) as well as the piping between the 4th stage feedwater heaters and the 3rd stage feedwater heaters were selected for EPU vibration monitoring.

Extraction Steam:

The extraction steam system will experience flow increases in the piping from the high pressure (HP) turbine to the 1st stage feedwater heaters and the piping from the low pressure (LP) turbine to the 2nd stage feedwater heaters of approximately 22% and 20%, respectively, as a result of EPU. The piping in these two portions of the extraction steam system was selected for EPU vibration monitoring.

Heater Drain:

The heater drain system will experience flow increases in the normal drain piping between the 1st and 2nd stage feedwater heaters and between the 2nd and 3rd stage feedwater heaters of approximately 22% and 20%, respectively, as a result of EPU. Based on a review of the piping configurations for these two portions of the heater drain system, the piping between the 2nd and 3rd stage feedwater heaters was selected for EPU vibration monitoring.

The portions of the CD, ES and HD systems selected for EPU vibration monitoring are summarized in Table 4-4.

Table 4-4
EPU Monitoring Locations for CD, ES and HD, BFN Units 1, 2 and 3

System	Description
CD	Piping from FW Heaters 3A/B/C to RFPs 1A/B/C
CD	Piping from FW Heaters 4A/B/C to FW Heaters 3A/B/C
ES	Piping from HP Turbine to FW Heaters 1A/B/C
ES	Piping from LP Turbine to FW Heaters 2A/B/C
HD	Piping from FW Heaters 2A/B/C to FW Heaters 3A/B/C

4.2.3 MS Components (Inside Containment)

BFN operating history indicates that excessive component vibrations are not expected at EPU conditions. In order to provide confirmation that component vibrations will be within acceptable limits at EPU conditions, selected components will be instrumented with accelerometers. The selected components include four safety-relief valves (SRV), one main steam isolation valve (MSIV), the inboard isolation valve for the MS drain piping, the inboard isolation valve for the reactor core isolation cooling (RCIC) turbine steam supply line and the inboard isolation valve for the high pressure coolant injection (HPCI) turbine steam supply line. Both the RCIC and HPCI lines are attached to the MS piping. The EPU component vibration monitoring locations are summarized in Table 4-5.

Component vibration acceptance criteria are based on the dynamic characteristics of the specific components, the frequency content of the excitation vibrations, including acoustic vibration; and industry experience for similar valves.

Table 4-5
EPU Component Monitoring Locations, BFN Units 1, 2 and 3

System	Valve ID	Direction	Description
MS	FCV-1-14	X	MS Line A Inboard Isolation Valve
MS		Y	
MS		Z	
MS	FCV-1-55	X	MS Drain Header Inboard Isolation Valve
MS		Y	
MS		Z	
RCIC	FCV-71-2	X	RCIC Steam Supply Line Inboard Isolation Valve
RCIC		Y	
RCIC		Z	
HPCI	FCV-73-2	X	HPCI Steam Supply Line Inboard Isolation Valve
HPCI		Y	
HPCI		Z	
MS	PCV-1-4	X	MS Line A SRV
MS		Y	
MS		Z	
MS	PCV-1-34	X	MS Line B SRV
MS		Y	
MS		Z	
MS	PCV-1-22	X	MS Line C SRV
MS		Y	
MS		Z	
MS	PCV-1-180	X	MS LINE D SRV
MS		Y	
MS		Z	

4.3 Data Acquisition and Reduction Methodology

The vibration data will be collected during EPU power ascension at pre-determined power levels using PC-based digital data acquisition systems (DAS). Each data set will be recorded using a minimum sample rate of 2000 samples per second per channel for a minimum duration of one minute.

The raw time history data for each power level will be processed for comparison to applicable acceptance criteria. The data processing will include integration, determination of peak, peak-to-peak and root mean square (rms) values, and high and low pass filtering, as applicable for specific monitoring locations, sensor types and acceptance criteria bases. Additional data processing, such as frequency analysis, will be performed to aid data analysis, as required.

4.4 Required Actions for Test Exceptions

The FIV data collected at each test plateau above CLTP will be processed and compared to the established acceptance criteria to demonstrate acceptability of the monitored piping and components. Level 1 and Level 2 criteria are established to aid in evaluation of the data and decision making during power ascension. A test exception will be generated if either Level 1 or Level 2 criteria are not satisfied.

The Level 1 criteria correspond to the calculated vibration limits. If a Level 1 criterion is not met, the plant will be placed in a safe condition until the issue can be resolved. This is accomplished by reducing power to the last power level where the Level 1 criteria were met. Once the issue is resolved, testing will be repeated at the applicable test plateau to verify that the Level 1 criteria are satisfied.

The Level 2 criteria are set at some percentage of the calculated vibration limits to provide sufficient warning that a Level 1 limit may be exceeded before the next test plateau. If a Level 2 criterion is not met, power will not be increased above the current power level until the issue is resolved. An evaluation will need to be completed to demonstrate that Level 1 criteria will still be satisfied at the next test plateau. Data may need to be retaken at the current test plateau depending on the resolution.

5.0 SUMMARY

Review of previous vibration data collected during BFN Unit 1 restart power ascension testing, as discussed in Section 3, indicates CLTP vibration levels well within acceptable limits. Extrapolation of the CLTP data to EPU power levels indicates that vibration of piping and components will not be adversely affected by EPU operation.

A confirmatory test program will be implemented to perform vibration monitoring during power ascension to EPU conditions. Piping and attached components on systems experiencing significant flow increases as a result of EPU will be included in the monitoring program. Piping vibration acceptance criteria will be based on ASME OM-3. Component vibration acceptance criteria will be based on component-specific dynamic characteristics and industry experience. Small bore piping assessments will be performed to identify potentially susceptible configurations, and any modifications required to reduce vibration susceptibility will be made prior to EPU power ascension.

Monitoring of inaccessible piping and components will be accomplished using vibration sensors wired to remote data acquisition systems. Accessible piping included in the monitoring program will be monitored either remotely or by performing visual observations or by taking vibration measurements using hand-held vibration instruments during power ascension to EPU conditions.

6.0 REFERENCES

1. GE Nuclear Energy, “Constant Pressure Power Uprate,” Licensing Topical Report NEDC- 33004P-A, Revision 4, Class III, July 2003.

2. BWR Owners’ Group EPU Committee, “Extended Power Uprate (EPU) Lessons Learned and Recommendations,” NEDO-33159 Revision 2, December 2008, BWR Owners’ Group EPU Committee.

3. U.S. Nuclear Regulatory Commission Regulatory Guide 1.20, “Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing,” Rev. 3.

4. ASME OM-2009, “Operation and Maintenance of Nuclear Power Plants,” Division 2, Part 3, “Vibration Testing of Piping Systems.”