Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-18-112

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ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Unit 3
Renewed Facility Operating License No. DPR-68
NRC Docket No. 50-296

Subject: **Extended Power Uprate – Unit 3 Flow Induced Vibration Summary Report**

Reference: NRC Letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 – Issuance of Amendments Regarding Extended Power Uprate (CAC Nos. MF6741, MF6742, and MF6743)," dated August 14, 2017 (ML17032A120)

In accordance with 10 CFR 50.92, the NRC issued the reference letter containing License Amendment Nos. 299, 323 and 283 to the Browns Ferry Nuclear Plant (BFN) Units 1, 2 and 3 Renewed Facility Operating Licenses (RFOLs) to increase the authorized maximum power level from 3458 megawatts thermal (MWt) to 3952 MWt. This change to power level is considered an extended power uprate (EPU).

The amended RFOLs contain specific license conditions that control the monitoring, evaluating, and taking prompt action in response to potential adverse flow effects as a result of the EPU on plant structures, systems, and components during initial EPU power ascension. This letter satisfies BFN Unit 3 License Condition 2.C(14)(b)5 by providing, within 90 days following completion of EPU power ascension testing, a flow induced vibration summary report for certain specified BFN Unit 3 piping and valve locations, including the vibration data and evaluation of the measured data compared to acceptance limits. BFN Unit 3 completed EPU power ascension testing for vibration monitoring of piping and valves on July 13, 2018. As a result, the due date for this submittal is October 11, 2018.

There are no new regulatory commitments associated with this submittal. If there are any questions or if additional information is needed, please contact Edward Schrull at (423) 751-3850.

Respectfully,

E. K. Henderson
Director, Nuclear Regulatory Affairs

Enclosure: Browns Ferry Nuclear Plant Unit 3 Flow Induced Vibration Summary Report

cc (Enclosure):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
State Health Officer, Alabama State Department of Public Health

Enclosure

Browns Ferry Nuclear Plant Unit 3 Flow Induced Vibration Summary Report

Introduction

This summary report provides an evaluation of flow induced vibration (FIV) data obtained at approximately 3630 MWt (91.9% power), 3803 MWt (96.2% power) and 3952 MWt (100% power) compared against vibration acceptance limits as required by Browns Ferry Nuclear Plant (BFN) Unit 3 License Condition 2.C(14)(b)5 issued with License Amendment No. 283, dated August 14, 2017.

FIV monitoring of piping and valves was performed during power ascension to extended power uprate (EPU) operating conditions per the BFN Unit 3 EPU Power Ascension Test Plan (PATP) – Vibration Monitoring, Rev. 1, dated April 2018. The following systems that could experience increased vibration due to higher flow rates resulting from EPU implementation were included in the scope of the FIV monitoring program:

- Main Steam (MS) – piping and selected valves
- High Pressure Coolant Injection (HPCI) – valve on steam supply line
- Reactor Core Isolation Cooling (RCIC) - valve on steam supply line
- Feedwater (FW) – piping
- Condensate (CD) – piping
- Heater Drain (HD) – piping
- Extraction Steam (ES) – piping

The above systems were instrumented with temporarily installed sensors to obtain vibration measurements at specified power plateaus per the PATP. Two minutes of vibration data were recorded at each plateau. The vibration data was processed to obtain vibration amplitudes in terms that could be directly compared to pre-established acceptance criteria (e.g., peak-to-peak displacement or rms acceleration). In addition to the monitoring locations required by the Unit 3 License Condition 2.C(14)(b)5, vibration data was collected for supplemental monitoring locations. This data was collected for information and plant trending purposes and therefore is not included in this report.

Some of the monitored locations on the MS and FW piping inside containment have both primary acceptance criteria in terms of displacement and secondary acceptance criteria in terms of acceleration. Because displacement is directly proportional to pipe stress it is the primary method of evaluating flow induced vibration.

The acceptance criteria were categorized as Level 1 and Level 2. The Level 1 criteria correspond to the acceptable steady-state vibration limits for the monitored piping and valves. The Level 2 limits, which were generally 80% or 85% of the Level 1 limits, were established to provide advance indication that measured vibrations were approaching the Level 1 limits during power ascension. The PATP specified required actions to follow if Level 2 or Level 1 limits were exceeded during power ascension.

Evaluation of Results

100% EPU power (approximately 3952 MWt) was attained on July 13, 2018. The measured vibration amplitudes at approximately 3630 MWt, 3803 MWt and 3952 MWt and corresponding Level 1 and Level 2 acceptance limit for each monitoring location are provided in Tables 1 through 6. Projected results are provided where valid data could not be obtained from a given sensor at a given power level. The projected value at a given power level is equal to the power level squared divided by the square of the power level corresponding to the last valid measured value, multiplied by the last valid measured value. The results provided in each table are evaluated below.

Table 1: Reactor Building MS and FW Piping

All of the measured MS vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured vibration amplitude for the MS piping exceeded 74% of the Level 1 limit (Location 83-V).

All of the measured and projected FW vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured or projected vibration amplitude for the FW piping exceeded 20% of the Level 1 limit (FW Loop B, Nozzle D, Location 43-T).

Projected values are provided for FW Loop A, Nozzle A, Location 9-R based on the measured value obtained at 87.5% power, which results in a projected value at 100% power that is approximately 4% of the Level 1 limit. At corresponding Location 9-R on FW Loop B, Nozzle F, the measured value at 100% power is also approximately 4% of the Level 1 limit, which provides further indication that the vibration at FW Loop A, Nozzle A, Location 9-R at 100% power would be anticipated to be less than the Level 1 limit.

Based on the results provided in Table 1 and the above discussion, the MS and FW piping vibrations in the reactor building are acceptable.

Table 2: MS, HPCI and RCIC Valves

All of the measured valve vibration amplitudes or associated resultant vibration amplitudes are less than the Level 1 and Level 2 limits. Because an SRV standpipe resonance near 110 Hz was not observed, the higher Level 2 limits shown in parentheses were applicable for the monitoring locations covered by Note 2 in the table. At 100% power, no resultant vibration amplitude for any valve exceeded 66% of the Level 1 limit (PCV-1-34). Therefore, the MS, HPCI and RCIC valve vibrations are acceptable.

Table 3: Turbine Building MS Piping

All of the measured and projected vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured or projected vibration amplitude, or resultant vibration amplitude where that is governing per Table 3, exceeded 60% of the Level 1 limit (Location G22 XY Resultant).

A projected value is provided for MS Line B, Location B125-X at 3952 MWt, based on the measured value at 3803 MWt, which is approximately 45% of the Level 1 limit. At corresponding Location D125-X on MS Line D, the measured value at 100% power is approximately 17% of the Level 1 limit, which provides further indication that the vibration at Location B125-X at 100% power would be anticipated to be less than the Level 1 limit.

At Location A310 on MS Line A, valid data could not be obtained due to sensor mounting bracket issues. At corresponding Location C290 on MS Line C, the projected XZ resultant vibration amplitude and the measured Y vibration amplitude at 100% power are approximately 13% of the Level 1 limit, which provides indication that the vibration amplitudes at Location A310 at 100% power would be anticipated to be less than the Level 1 limits. Location A310 (as well as Locations B125, D125, C290 and other locations) was also observed using a remote controlled video camera to verify that no abnormal vibrations were occurring. The visual observations provide further indication that the vibration amplitudes at Location A310 at 100% power would be anticipated to be less than the Level 1 limits.

Projected values are provided for Location C290-X based on the measured value obtained at 87.5% power, which results in a projected XZ resultant vibration amplitude that is approximately 13% of the Level 1 limit. The measured Y vibration amplitude at Location C290 at 100% power is also approximately 13% of the Level 1 limit, which provides further indication that the resultant XZ vibration amplitude at Location C290 at 100% power would be anticipated to be less than the Level 1 limit. As discussed above, a video camera was also used to verify that no abnormal vibrations were occurring at Location C290.

It is also noted that viscoelastic dampers were installed at several locations on the MS piping in the turbine building during the outage prior to EPU power ascension to mitigate MS piping vibrations. Viscoelastic dampers were installed near locations A310, C290, B125 and D125, as well as other locations. Installation of the viscoelastic dampers provided added assurance that vibrations of the MS piping in the turbine building would be acceptable at EPU conditions.

Projected values are provided for Location G22-Y based on the measured value obtained at 87.5% power, which results in a projected XY resultant vibration amplitude that is approximately 60% of the Level 1 limit at 100% power. The measured vibration amplitude in the X direction at 100% power is approximately 24% of the Level 1 limit, which provides further indication that the XY resultant vibration amplitude at Location G22 at 100% power would be anticipated to be less than the Level 1 limit.

Projected values are provided for Location G57-Z based on the measured value obtained at 83.1% power, which results in a projected vibration amplitude that is approximately 41% of the Level 1 limit at 100% power. At Location G99-X, which is approximately 12 feet from Location G57-Z, the measured vibration amplitude at 100% power is approximately 17% of the Level 1 limit, which provides further indication that the vibration amplitude at Location G57-Z at 100% power would be anticipated to be less than the Level 1 limit.

Based on the results provided in Table 3 and the above discussion, the MS piping vibrations in the turbine building are acceptable.

Table 4: Turbine Building FW Piping

All of the measured vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured vibration amplitude at any location exceeded

56% of the Level 1 limit (Location FW-21-Z). Therefore, the FW piping vibrations in the turbine building are acceptable.

Table 5: CD, HD and ES Piping

All of the measured and projected CD vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured or projected vibration amplitude for the CD piping exceeded 30% of the Level 1 limit (Location BB25A-Y & -Z).

Projected values are provided for Location BB25A-Y at 3803 MWt and 3952 MWt, based on the measured value at 3630 MWt, which results in a projected value that is approximately 30% of the Level 1 limit at 100% power. The measured values in the X and Z directions at Location BB25A at 100% power are approximately 18% and 30%, respectively, of the Level 1 limit, which provides further indication that the vibration at Location BB25A-Y at 100% power would be anticipated to be less than the Level 1 limit.

All of the measured HD vibration amplitudes are less than the Level 1 limits. At 100% power, no measured vibration amplitude for the HD piping exceeded 56% of the Level 1 limit (Location 110-130-Z).

All of the measured and projected ES vibration amplitudes are less than the Level 1 limits. At 100% power, no measured or projected vibration amplitude for the ES piping exceeded 43% of the Level 1 limit (Location X247-X).

Projected values are provided for Location X247-Y based on the measured value at 87.5% power, which results in a projected value that is approximately 17% of the Level 1 limit at 100% power. The measured values in the X and Z directions at Location X247 at 100% power are approximately 43% and 38%, respectively, of the Level 1 limit, which provides further indication that the vibration at Location X247-Y at 100% power would be anticipated to be less than the Level 1 limit.

Based on the results provided in Table 5 and the above discussion, the CD, HD and ES piping vibrations are acceptable.

Table 6: Reactor Building MS and FW Piping Supplemental Data

All of the measured MS vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured vibration amplitude for the MS piping exceeded 17% of the Level 1 limit (Locations 246-T and 50-Y).

All of the measured and projected FW vibration amplitudes are less than the Level 1 and Level 2 limits. At 100% power, no measured or projected vibration amplitude for the FW piping exceeded 13% of the Level 1 limit (Location 28-Z).

Projected values are provided for FW Loop A, Nozzle A, Location 9-R based on the measured value obtained at 87.5% power, which results in a projected value at 100% power that is approximately 5% of the Level 1 limit. At corresponding Location 9-R on FW Loop B, Nozzle F, the measured value at 100% power is approximately 3% of the Level 1 limit, which provides further indication that the vibration at FW Loop A, Nozzle A, Location 9-R at 100% power would be anticipated to be less than the Level 1 limit.

Based on the results provided in Table 6 and the above discussion, the supplemental MS and FW piping vibration measurements in the reactor building are acceptable.

Conclusion

The piping and valve vibration data provided in Tables 1 through 6 have been evaluated as required by BFN Unit 3 License Condition 2.C(14)(b)5. The evaluation results demonstrate that the piping and valve vibration amplitudes are less than the associated acceptance limits and, thus, are acceptable.

Table 1. FIV Monitoring Results for Reactor Building MS and FW Piping

Description	Location-Direction	Measured Displacement (mils pk-pk)			Level 2 Limit (mils pk-pk)	Level 1 Limit (mils pk-pk)
		3630 MWt	3803 MWt	3952 MWt		
MS Line A	15-R	14	17	19	72	90
	15-T	16	17	22	26	32
	83-R	11	13	16	50	63
	83-V	31	31	31	34	42
MS Line B	3A/3B-R	7	8	9	42	52
	3A/3B-T	11	12	14	25	31
	19B-V	6	7	8	62	77
MS Line C	246-R	7	9	9	49	61
	246-T	16	16	20	28	35
	40-X	15	16	19	21	26
	40-Y	1	3	3	62	78
	40-Z	7	9	9	38	48
RPV Head Vent	50-Y	1	2	2	14	17
	50-Z	6	7	7	19	24
FW Loop A, Nozzle A	9-R	2[(1)]	2[(1)]	3[(1)]	54	68
	19A-V	5	6	6	48	60
FW Loop A, Nozzle B	28-X	4	4	4	55	69
	28-Z	2	2	3	18	22
FW Loop A, Nozzle C	43-R	8	6	8	59	74
	43-T	12	12	13	54	67
FW Loop B, Nozzle F	9-R	3	3	4	86	107
	15-V	6	6	7	44	55
FW Loop B, Nozzle E	25-X	3	3	3	36	45
	25-Z	9	8	8	106	132
FW Loop B, Nozzle D	43-R	9	11	12	66	83
	43-T	11	13	12	48	60

1. Projected from measured value of 2 mils pk-pk at 87.5% power (3458 MWt).

Table 2. FIV Monitoring Results for MS, HPCI and RCIC Valves

Description	Direction	Measured Acceleration (g-rms)			Level 2 Limit (g-rms)	Level 1 Limit (g-rms)
		3630 MWt	3803 MWt	3952 MWt		
MS Line A Inboard Isolation Valve (FCV-1-14)	X	0.048	0.062	0.067	0.058 (0.221)[2]	0.260
	Y	0.065	0.070	0.074	0.090 (0.116)[2]	0.136
	Z	0.066	0.073	0.078	0.089 (0.328)[2]	0.386
	Resultant[1]	0.104	0.119	0.127	0.140 (0.412)[2]	0.485
MS Drain Header Inboard Isolation Valve (FCV-1-55)	X	0.028	0.032	0.043	0.110 (0.140)[2]	0.165
	Y	0.033	0.038	0.063	0.140 (0.182)[2]	0.214
	Z	0.067	0.071	0.083	0.100 (0.133)[2]	0.157
	Resultant[1]	0.080	0.087	0.113	0.200 (0.266)[2]	0.313
RCIC Steam Supply Line Inboard Isolation Valve (FCV-71-2)	X	0.032	0.033	0.038	0.110 (0.141)[2]	0.166
	Y	0.026	0.027	0.037	0.140 (0.183)[2]	0.215
	Z	0.063	0.058	0.071	0.100 (0.133)[2]	0.157
	Resultant[1]	0.075	0.072	0.089	0.200 (0.267)[2]	0.314
HPCI Steam Supply Line Inboard Isolation Valve (FCV-73-2)	X	0.072	0.072	0.082	0.200 (0.318)[2]	0.374
	Y	0.117	0.126	0.148	0.130 (0.199)[2]	0.234
	Z	0.051	0.054	0.062	0.130 (0.199)[2]	0.234
	Resultant[1]	0.147	0.155	0.180	0.270 (0.424)[2]	0.499
MS Line A SRV (PCV-1-4)	X	0.05	0.06	0.08	0.59	0.69
	Y	0.06	0.07	0.18	0.77	0.90
	Z	0.05	0.06	0.08	0.34	0.40
	Resultant[1]	0.09	0.11	0.21	1.03	1.20
MS Line B SRV (PCV-1-22)	X	0.11	0.13	0.14	0.59	0.69
	Y	0.26	0.36	0.40	0.77	0.90
	Z	0.09	0.11	0.12	0.34	0.40
	Resultant[1]	0.30	0.40	0.44	1.03	1.20
MS Line C SRV (PCV-1-34)	X	0.11	0.13	0.14	0.59	0.69
	Y	0.52	0.63	0.73	0.77	0.90
	Z	0.22	0.25	0.28	0.34	0.40
	Resultant[1]	0.58	0.69	0.79	1.03	1.20
MS Line D SRV (PCV-1-180)	X	0.06	0.07	0.08	0.59	0.69
	Y	0.07	0.08	0.14	0.77	0.90
	Z	0.10	0.11	0.12	0.34	0.40
	Resultant[1]	0.14	0.15	0.20	1.03	1.20

1. The measured accelerations are acceptable if the resultant of the measured accelerations is less than the Level 1 limit.
2. The Level 2 limit can be increased to the value in parentheses if an SRV standpipe resonance near 110 Hz is not occurring.

Table 3. FIV Monitoring Results for Turbine Building MS Piping

Description	Location-Direction	Measured Displacement (mils pk-pk)			Level 2 Limit (mils pk-pk)	Level 1 Limit (mils pk-pk)
		3630 MWt	3803 MWt	3952 MWt		
Main Steam Line B 24"	B125-X	21	17	18 (3)	32	40
Main Steam Line D 24"	D125-X	29	29	24	114	142
Bypass Valves 8" Line	L75-Y	14	15	14	133	166
	L75-Z	4	5	8	158	198
Main Steam Line A 28"	A310-X	(4)	(4)	(4)	26	32
	A310-Y	(4)	(4)	(4)	121	151
	A310-Z	(4)	(4)	(4)	99	124
	XZ Resultant(1)	(4)	(4)	(4)	102	128
Main Steam Line C 28"	C290-X	11(5)	12(5)	13(5)	67	84
	C290-Y	19	20	17	101	126
	C290-Z	37	31	29	193	241
	XZ Resultant(1)	39	33	32	204	255
Main Steam Line C 1" Line	M28-X	22	16	15	85	106
	M28-Z	57	54	54	53	66
	XZ Resultant(1)	61	56	56	100	125
Main Steam Line D 1" Line	M28-X	23	23	18	85	106
	M28-Z	30	22	21	53	66
	XZ Resultant(1)	38	32	28	100	125
Stop Valve 2	F37-X	47	42	36	215	269
	F37-Z	24	23	22	105	131
Control Valve 1 1" Line	G22-X	28	21	20	66	82
	G22-Y	51(6)	56(6)	60(6)	52	65
	XY Resultant(1)	58	60	63	84	105
Control Valve 4 1" Line	G99-X	31	23	16	76	95
Control Valve 3 2.5" Line	G57-Z	18(7)	20(7)	22(7)	43	54

1. The measured displacements in the X and Z directions are acceptable if the resultant of the measured displacements in the X and Z directions is less than the Level 1 limit.
2. The measured displacements in the X and Y directions are acceptable if the resultant of the measured displacements in the X and Y directions is less than the Level 1 limit.
3. Projected from measured value of 17 mils pk-pk at 96.2% power (3803 MWt).
4. See "Evaluation of Results" section.
5. Projected from measured value of 10 mils pk-pk at 87.5% power (3458 MWt).
6. Projected from measured value of 46 mils pk-pk at 87.5% power (3458 MWt).
7. Projected from measured value of 15 mils pk-pk at 83.1% power (3285 MWt).

Table 4. FIV Monitoring Results for Turbine Building FW Piping

Description	Location-Direction	Measured Displacement (mils pk-pk)			Level 2 Limit (mils pk-pk)	Level 1 Limit (mils pk-pk)
		3630 MWt	3803 MWt	3952 MWt		
RFP 1A 18" Discharge	A38-X	30	35	42	78	98
	A38-Y	14	11	12	53	66
	47-Z	17	17	14	228	285
RFP 1B 18" Discharge	142A-X	7	7	6	78	97
	142A-Y	11	11	10	58	73
	132A-Z	13	11	7	258	323
RFP 1C 18" Discharge	80A-Y	5	5	4	62	78
Heater String A2 18" Line	215B-X	6	6	5	51	64
	215B-Z	12	16	12	110	137
Heater String A1 18" Line	95B-X	12	14	11	30	37
	95B-Y	7	8	7	26	33
Heater String C1 18" Line	30A-Y	2	2	2	23	29
	30A-Z	7	8	6	21	26
RFW 24" Disch Return	135B-X	6	8	8	25	31
	135B-Z	16	18	15	22	28
FW Item No. 21	FW-21-X	19	39	34	71	89
	FW-21-Z	64	55	50	71	89
FW Item No. 31	FW-31-X	5	4	4	128	160
	FW-31-Z	3	3	2	59	74
FW Item No. 42	FW-42-X	8	7	9	82	103
	FW-42-Z	42	50	46	150	187
FW Item No. 52	FW-52-X	6	7	6	82	103
	FW-52-Z	39	33	34	150	187
FW Item No. 55	FW-55-Y	4	4	3	26	32
	FW-55-Z	10	8	8	32	40

Table 5. FIV Monitoring Results for CD, HD and ES Piping

Description	Location-Direction	Measured Displacement (mils pk-pk)			Level 2 Limit (mils pk-pk)	Level 1 Limit (mils pk-pk)
		3630 MWt	3803 MWt	3952 MWt		
CD-01	50-X	17	24	23	105	131
	50-Y	25	26	28	118	148
	50-Z	24	31	29	158	198
CD-02	BB25A-X	10	11	11	48	60
	BB25A-Y	13	14[1]	15[1]	40	50
	BB25A-Z	11	12	14	38	47
HD-01	380-385-Y	9	6	5	143	179
	380-385-Z	10	8	8	101	126
HD-02	110-130-X	33	32	23	42	53
	110-130-Y	2	2	2	34	42
	110-130-Z	43	44	41	58	73
ES-01	CB37-X	4	5	5	146	183
	CB37-Y	5	5	5	86	107
	CB37-Z	5	5	5	79	99
ES-02	HA02-X	11	11	12	87	109
	HA02-Y	5	5	5	142	178
	HA02-Z	3	2	3	105	131
ES-03	X247-X	12	13	31	58	72
	X247-Y	11[2]	12[2]	13[2]	61	76
	X247-Z	14	16	16	34	42

1. Projected from measured value of 13 mils pk-pk at 91.9% power (3630 MWt).
2. Projected from measured value of 10 mils pk-pk at 87.5% power (3458 MWt).

Table 6. Supplemental FIV Monitoring Results for Reactor Building MS and FW Piping

Description	Location-Direction	Measured Acceleration (g's pk)			Level 2 Limit (g's pk)	Level 1 Limit (g's pk)
		3630 MWt	3803 MWt	3952 MWt		
MS Line A	15-R	0.2	0.2	0.2	3.4	4.2
	15-T	0.2	0.2	0.2	1.1	1.4
MS Line B	3A/3B-R	0.2	0.2	0.2	1.8	2.2
	3A/3B-T	0.2	0.2	0.2	1.1	1.4
	19B-V	0.2	0.2	0.2	1.9	2.4
MS Line C	246-R	0.1	0.1	0.2	2.1	2.6
	246-T	0.2	0.2	0.2	1.0	1.2
RPV Head Vent	50-Y	0.0	0.0	0.1	0.5	0.6
	50-Z	0.1	0.1	0.1	1.0	1.2
FW Loop A, Nozzle A	9-R	0.1[1]	0.1[1]	0.1[1]	1.7	2.1
FW Loop A, Nozzle B	28-X	0.1	0.1	0.1	2.6	3.3
	28-Z	0.1	0.1	0.1	0.6	0.8
FW Loop B, Nozzle F	9-R	0.1	0.1	0.1	2.7	3.4
FW Loop B, Nozzle D	43-R	0.1	0.1	0.2	1.6	2.0
	43-T	0.1	0.1	0.1	1.0	1.3

1. Projected from measured value of 0.1 g's pk at 87.5% power (3458 MWt).