ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - STEAM DRYER LIMIT CURVES

CDI TECHNICAL NOTE NO. 07-30NP, "LIMIT CURVE ANALYSIS WITH ACM REV. 4 FOR POWER ASCENSION AT BROWNS FERRY NUCLEAR UNIT 1"

(NON-PROPRIETARY VERSION)

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Attached is the **Non-Proprietary Version** of CDI Technical Note No. 07-30NP, "Limit Curve Analysis with ACM Rev. 4 for Power Ascension at Browns Ferry Nuclear Unit 1."

C.D.I. Technical Note No. 07-30NP

# Limit Curve Analysis with ACM Rev. 4 for Power Ascension at Browns Ferry Nuclear Unit 1

Revision 0

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# Table of Contents

# 1. Introduction

During power ascension of Browns Ferry Nuclear Unit 1 (BFN1), from Current Licensed Thermal Power (CLTP) to Extended Power Uprate (EPU), TVA is required to monitor the dryer stresses at plant power levels that have not yet been achieved. Limit curves provide an upper bound safeguard against the potential for dryer stresses becoming higher than allowable, by estimating the not-to-be-exceeded main steam line pressure levels. In the case of BFN1, in-plant main steam line data have been analyzed at CLTP conditions (based on Unit 2 data) to provide steam dryer hydrodynamic loads [1]. EPU is 120% of Original Licensed Thermal Power (OLTP); CLTP is 105% of OLTP. A finite element model stress analysis has been undertaken on the CLTP loads [2]. These existing loads provide the basis for generation of the limit curves to be used during BFN1 power ascension.

Continuum Dynamics, Inc. (C.D.I.) has developed an acoustic circuit methodology (ACM) that determines the relationship between main steam line data and pressure on the steam dryer [3]. This methodology and the use of a finite element model analysis provide the computational algorithm from which dryer stresses at distinct steam dryer locations can be tracked through power ascension. Limit curves allow TVA to limit dryer stress levels, by comparing the main steam line pressure readings – represented in Power Spectral Density (PSD) format – with the upper bound PSD derived from existing in-plant data.

This technical note summarizes the proposed approach that will be used to track the anticipated stress levels in the BFN1 steam dryer during power ascension, utilizing Rev. 4 of the ACM [4], and the options available to TVA should a limit curve be reached.

# 2. Approach

The limit curve analysis for BFN1, to be used during power ascension, is patterned after the approach followed by Entergy Vermont Yankee (VY) in its power uprate [5]. In the VY analysis, two levels of steam dryer performance criteria were described: (1) a Level 1 pressure level based on maintaining the ASME allowable alternating stress value on the dryer, and (2) a Level 2 pressure level based on maintaining 80% of the allowable alternating stress value on the dryer. The VY approach is summarized in [6].

To develop the limit curves for BFN1, the stress levels in the dryer were calculated for the current plant acoustic signature, at CLTP conditions, and then used to determine how much the acoustic signature could be increased while maintaining stress levels below the stress fatigue limit. During power ascension, strain gage data will be converted to pressure in PSD format at each of the eight main steam line locations, for comparison with the limit curves. The strain gage data will be monitored throughout power ascension to observe the onset of discrete peaks, if they occur.

The finite element analysis of in-plant CLTP data found a lowest alternating stress ratio of 2.0 [2] as summarized in Table 1. The minimum stress ratios include the model bias and uncertainties for specific frequency ranges as suggested by the NRC [7]. The results of the ACM Rev. 4 analysis (based on Quad Cities Unit 2, or QC2, in-plant data) are summarized in Table 2 (a negative bias is conservative). Note that the standpipe excitation frequency in BFN1 is anticipated to be 218 Hz, and that the uncertainty determined around the QC2 excitation frequency of 155 Hz has been applied to the 216 to 220 Hz frequency interval. Note also that it is anticipated that the 218 Hz will be mitigated by plugging the blank standpipes prior to power ascension, and that the stress analysis is based on this modification. The additional bias and uncertainties, as identified in [8], [9] and [10], are shown in Table 3. SRSS of the uncertainties, added to the ACM bias, results in the total uncertainties shown in Table 4. These uncertainties were applied to the finite element analysis, resulting in the minimum stress ratio of 2.0.

Table 1. Peak Stress Limit Summary for ACM Rev. 4

| | | |
|---|---|---|
| Peak Stress Limit | 13,600 psi (Level 1) | 10,880 psi (Level 2) |
| Minimum Stress Ratio | 2.0 | 1.6 |

Table 2. Bias and uncertainty for ACM Rev. 4

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Table 3. BFN1 additional uncertainties (with references cited)

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(3)]]

Table 4. BFN1 total uncertainty

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(3)]]

## 3. Limit Curves

Limit curves were generated from the in-plant CLTP strain gage data collected on Unit 2 in December 2006 and reported in [1]. These data were filtered across the frequency ranges shown in Table 5 to remove noise and extraneous signal content, as suggested in [11]. The resulting PSD curves for each of the eight strain gage locations were used to develop the limit curves, shown in Figures 1 to 4. Level 1 limit curves are found by multiplying the main steam line pressure PSD base traces by the square of the corrected limiting stress ratio ($2.0^2 = 4.0$), while the Level 2 limit curves are found by multiplying the PSD base traces by 0.64 of the square of the corrected limiting stress ratio (recovering 80% of the limiting stress ratio, or $0.80^2 \times 2.0^2 = 0.64 \times 4.0 = 2.56$), as PSD is related to the square of the pressure.

Consistent with the stress analysis [2], the peaks at 218 Hz on all eight strain gage signals were also filtered from the main steam line data prior to the development of the limit curves. BFN1 intends to mitigate the effect of the eight blind standpipes on main steam lines A and D, prior to power ascension.

Table 5. Exclusion frequencies for BFN2 at CLTP conditions (VFD = variable frequency drive, Recirc = recirculation pumps)

| Frequency Range (Hz) | Exclusion Cause |
|---|---|
| 0 – 2 | Mean |
| 59.9 – 60.1 | Line Noise |
| 119.9 – 120.1 | Line Noise |
| 179.9 – 180.1 | Line Noise |
| 239.9 – 240.1 | Line Noise |
| 44.7 – 46.0 | VFD (1x) |
| 90.8 – 91.0 | VFD (2x) |
| 136.1 – 136.5 | VFD (3x) |
| 181.6 – 181.8 | VFD (4x) |
| 227.1 – 227.4 | VFD (5x) |
| 112.7 – 113.2 | Recirc Pump A Speed (5x) |
| 110.4 – 111.7 | Recirc Pump B Speed (5x) |

[[

[(3)]]]

Figure 1. Level 1 (black) and Level 2 (red) limit curves for main steam line A, compared against the base curves (blue) over the frequency range of interest: A upper strain gage location (top); A lower strain gage location (bottom).

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(3)]]

Figure 2. Level 1 (black) and Level 2 (red) limit curves for main steam line B, compared against the base curves (blue) over the frequency range of interest: B upper strain gage location (top); B lower strain gage location (bottom).

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(3)]]

Figure 3. Level 1 (black) and Level 2 (red) limit curves for main steam line C, compared against the base curves (blue) over the frequency range of interest: C upper strain gage location (top); C lower strain gage location (bottom).

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Figure 4. Level 1 (black) and Level 2 (red) limit curves for main steam line D, compared against the base curves (blue) over the frequency range of interest: D upper strain gage location (top); D lower strain gage location (bottom).

# 4. References

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3. Continuum Dynamics, Inc. 2005. Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes (Rev. 6). C.D.I. Report No. 04-09 (Proprietary).

4. Continuum Dynamics, Inc. 2007. Methodology to Predict Full Scale Steam Dryer Loads from In-Plant Measurements, with the Inclusion of a Low Frequency Hydrodynamic Contribution (Rev. 1). C.D.I. Report No. 07-09 (Proprietary).

5. Entergy Nuclear Northeast. 2006. Entergy Vermont Yankee Steam Dryer Monitoring Plan (Rev. 4). Docket 50-271. No. BVY 06-056. Dated 29 June 2006.

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7. NRC Request for Additional Information on the Hope Creek Generating Station, Extended Power Uprate. 2007. TAC No. MD3002. RAI No. 14.67.

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