Attachment 3

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South Texas Unit 3 Main Steam Line: Acoustic Screening Results

Westinghouse

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

An initial acoustic screening was performed for the main steam lines (MSLs) of South Texas Unit 3. The purpose was to determine the range of critical flow velocities in the MSLs that are most likely to cause shear wave resonance of the safety relief valves (SRVs), standpipes, and other branches connected to the MSLs.

The onset velocities for single and double vortex resonance were calculated for various standpipe/SRV configurations. [

]b

[ ]a, b

1 INTRODUCTION

Several nuclear power plants of the boiling water reactor (BWR) fleet have experienced the excitation of acoustic standing waves in closed side branches by the steam flow through the MSLs. The pulsation amplitudes generated by this acoustic resonance have caused significant degradation to steam dryers and other equipment such as SRVs.

The advanced boiling water reactor (ABWR) design is similar in layout and operating conditions to the traditional BWRs and is similarly prone to the excitation of acoustic standing waves in its closed side branches. Unlike existing BWRs, the South Texas Unit 3 ABWR is not yet constructed in the United States. The design, as described in the combined license application (COLA), does not include the detailed information such as specific SRV manufacturer or geometry, standpipe length, etc. Therefore, the implementation of the COLA design for South Texas Unit 3 will be developed during the detailed design of the piping systems, and thus, can be engineered to be outside the regions of concern for acoustic resonance. The ABWR units constructed in Japan have not reported any steam dryer acoustic resonance issues. The detailed design of those ABWRs is included in this acoustic screening along with other manufacturers and piping detail options.

The purpose of this report is three-fold:

1. To present the range of critical flow velocities in the MSLs of the South Texas Unit 3 Nuclear Power Plant that are most likely to cause shear wave resonance of the safety relief valves, standpipes, and other branches connected to the MSLs.

2. To assess possible detailed design configurations for the standpipe/SRV combination in order to avoid an onset velocity less than the steam flow at 100% rated core thermal power.

3. To present preliminary strain gauge installation locations on the MSLs [
]a

1.1 STEAM DRYER DEGRADATIONS IN THE BWR FLEET

On July 11, 2002, a BWR was shut down due to the degradation of the steam dryer. This plant had operated approximately 90 days under extended power uprate (EPU) conditions when the plant experienced several anomalous readings related to reactor pressure, water level, steam flow, and MSL moisture content.

Following plant shutdown, an inspection of the plant revealed that a steam dryer cover plate adjacent to one of the outer bank inlet hoods had failed, allowing steam to bypass the dryer flow path. The root cause investigation of the cover plate failure identified a potential cause to be the high-cycle fatigue generated by the near coincidence of an acoustic natural frequency in the steam plenum and/or other steam system cavities, such as MSL branch lines and the vortex shedding frequency associated with flow over some of the discontinuities present in the steam delivery system. At the increased steam flow rates associated with EPU, the acoustic standing wave frequency and the vortex shedding frequency may have become nearly aligned, causing resonant response at a frequency coinciding with the structural natural frequency of the cover plate that failed.

Subsequent to the failure observed in 2002, additional failures were observed during 2003 and 2004 in the dryer outer hoods and tie bars. The steam dryers at two additional plants also showed incipient cracking at the same initiation locations, though the cracks at these units did not grow to failure.

2 ANALYSIS METHODOLOGY AND CONSIDERATIONS

The method for screening the potential for MSL acoustic excitation is documented in [1]. Steam lines experience flow instabilities at intersections where side branches originate for housing subsystems such as SRVs. These instabilities can cause an acoustic resonance condition [

]a

2.1 FLOW CONDITIONS AT 100% RATED CORE THERMAL POWER

[

]b

[ ]a, b Equation 2-1

[

]a, b

2.2 STANDPIPE / SAFETY RELIEF VALVE CONFIGURATIONS

[

]a

[

]a

Table 2-1 [ ]a,c

[ ]a, b, c

[

]a

[

]a

a, b, c

Figure 2-1 [ ]a,c
(dimensions in inches)

The standpipe/SRV combinations considered for this analysis were:

a, b, c

[

]a, c

2.3 ADDITIONAL BRANCH LINE CONNECTIONS

Branch lines connected to the MSLs, other than standpipes/SRVs, were screened for susceptibility to acoustic resonance. The MSLs have multiple drain lines and instrumentation tubing connected to them at different locations. [ ]a, c

[ ]a, c

2.4 ADDITIONAL DESIGN POSSIBILITIES

[ ]a, c

3 RESULTS

3.1 SAFETY RELIEF VALVES

Table 3-1 summarizes the results for the various standpipe/SRV combinations considered.

a, b, c

Table 3-1 Acoustic Frequency and Onset Velocity of Standpipe/SRV Combinations Considered			

[

][a]

a, b, c

Figure 3-1 Steam Flow Rate Relative to Onset Velocities

3.2 OPTIMAL STRAIN GAUGE SPACING

[

][a]

[ ][a]

Equation 3-1

[

][a]

[

][a, b]

Table 3-2 Optimal Strain Gauge Spacing [a, b]

[

][a, b]

[

][a, b, c]

4 CONCLUSIONS

Based on a detailed acoustic model [

] b

[

] a, b

[

] a, b, c

[

] a, b

[

] a, b

5 REFERENCES

1. *BWR Vessel and Internals Project, Methodologies for Demonstrating Steam Dryer Integrity for Power Uprate.* Electric Power Research Institute, Palo Alto, CA: October 2008. BWRVIP-194.

2. [ ]c