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SUSQUEHANNA STEAM ELECTRIC STATION
RESPONSE TO VERBAL RAI RELATED TO
OFFGAS SYSTEM REVIEW
PLA-4964 FILE R41-2

Docket Nos. 50-387
and 50-388

This letter and attachment provides PP&L, Inc.'s response to the NRC staff's question related to their review and approval of PP&L's determination that the Susquehanna SES offgas system can withstand hydrogen detonations.

Please contact J. M. Kenny at (610) 774-7535 if there are any questions concerning the attached response.

Sincerely,

R. G. Byram

Attachment

copy: NRC Region I
Mr. K. Jenison, NRC Sr. Resident Inspector
Mr. V. Nerses, NRC Sr. Project Manager

A001

Summary

Dynamic analyses were performed to evaluate the response of the Susquehanna Steam Electric Station offgas piping due to potential transient conditions that could lead to the presence of detonable hydrogen mixtures within the offgas system downstream of the recombiners. Assuming ignition of the detonable hydrogen mixture, a bounding case time force history was developed using an impulse load for piping elbows for 8-inch and 4-inch pipe. As a bounding case, the largest piping in the system with an associated elbow was chosen for analysis using the maximum expected peak pressure that could occur within that piping diameter. This bounding case was determined to be the 8-inch piping where peak detonation pressures are potentially as high as 1216 psia. A confirmatory case was also examined using 4-inch piping where peak pressures as high as 2550 psia can develop as a result of hydrogen detonation.

The result of the analysis shows that, following the postulated hydrogen detonation, the highest calculated moment occurs at the elbow-to-pipe location. For the assumed bounding case for 8-inch pipe, as summarized in the table below, the stress is 10,520 psi and for the 4-inch pipe, 6441 psi. Both stresses are well below the ANSI/ASME B31.1 code allowable stress limit of 1.2 S_h, where 1.2 S_h for the analyzed piping is 18,000 psi. Therefore, pipe stresses within the offgas system elbows due to bending moments resulting from a detonation event are well within the B31.1 limit.

Limiting Case Summary

Case	Calculated Stress, psi	Code Allowable Stress, psi
8-inch pipe	10,520	18,000

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1. Introduction

In the offgas piping, low probability events can result in a transient condition that will lead to the presence of potentially detonable hydrogen mixtures. The potential impact of hydrogen ignition on the offgas system pressure boundary has been previously analyzed for Susquehanna in Reference 1. The results of that study show that the Susquehanna offgas piping has sufficient design margin to withstand multiple ignition events without exceeding the dynamic yield stresses. Since the completion of the Reference 1 study, the potential for impulse loading and its effect on piping bending moments at system elbows has been identified. Actual bending-moment failure of elbows was reported in prior work (Reference 2). The failure occurred in light weight (sheet metal) ducting. While the failed sheet metal ducting was only 13% of the thickness that would be used for the same pipe diameter in the Susquehanna offgas system, it was considered reasonable to analyze for the potential for a similar bending-moment failure in the plant piping. This report summarizes a bounding case analysis for the stresses that may occur in the offgas system elbows due to bending moments following a potential hydrogen detonation event within the piping.

2. Methods and Assumptions

The scope of this evaluation is the dynamic qualification of piping elbows due to potential detonation impulse loads and resulting bending moments. For bounding cases representative of the Susquehanna offgas piping systems, peak pressures developed following ignition as a function of time were applied within piping elbows to calculate the bending moment and stress. The calculated stresses were then compared with B31.1 allowable values to determine whether the piping remains within the allowable stress limit. Because a detailed analysis of the entire Susquehanna offgas system piping configuration was not performed, the following extremely conservative assumptions were used to ensure, with a high degree of certainty, that the results would be bounding:

1. The detonation event is assumed to be fully developed such that the maximum postulated pressures, as described in Reference 1, are assumed to occur within the elbow. This assumes that a straight run of piping greater than seven pipe diameters exists upstream of the elbow. For those elbows in the system with shorter straight piping runs upstream, the calculated stresses will be approximately a factor of ten lower than were calculated for the bounding case.
2. It is assumed that the peak pressures will persist as the reflected pulse travels throughout the entire length of the elbow, even though they will actually diminish

with distance from the back of the elbow due to pipe friction (which was conservatively ignored).

3. It is assumed that the time force history of the pressure wave is such that the duration of the peak pressure is 300 μ seconds, even though measurements show that the actual peak is approximately 1 μ second.
4. The resulting stresses were compared to the B31.1 allowable values (1.2 S_h), even though it is appropriate to use dynamic yield stresses measured under high strain rate conditions. This approach is conservative by more than a factor of three.

3. Analysis

Dynamic analyses were performed for piping elbows for 8-inch and 4-inch pipe as described above. The model is a simple L shape elbow. For both pipe sizes, the straight run of piping is assumed to extend 200 inches from the elbow in both directions. The time force history was developed using an impulse load that, as typically reported in the literature, for example in Reference 3, rises in approximately 1 μ second to its maximum value (2550 psi for 4-inch pipe and 1216 psi for 8-inch pipe), and then returns to zero within approximately 500 μ seconds. The peak pressure force load history was extended from 1 μ second to 300 μ seconds to create a total impulse load of 1 lb.sec/in^2, an extremely conservative value reported in Reference 4.

Time force history for 8 inch pipe

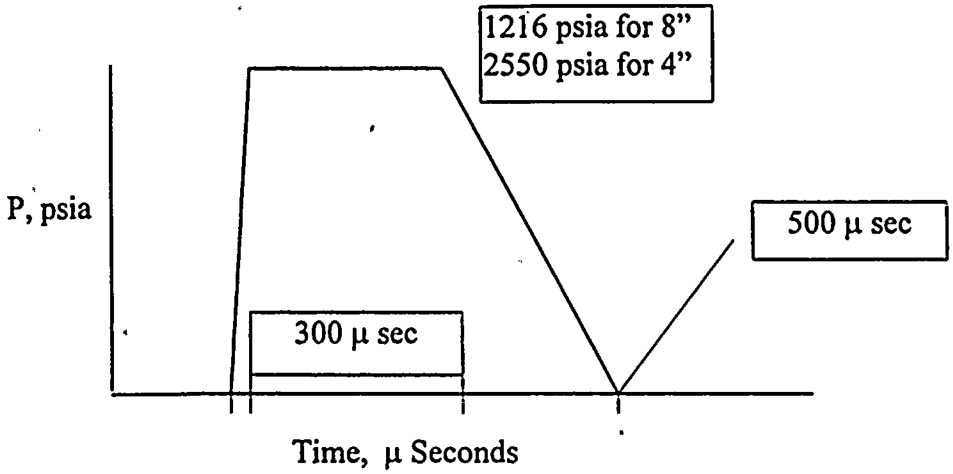
Time μ sec.	Force lbf
0	0
2	0
3	1216 x A
303	1216 x A
503	0
600	0

Time force history for 4 inch pipe

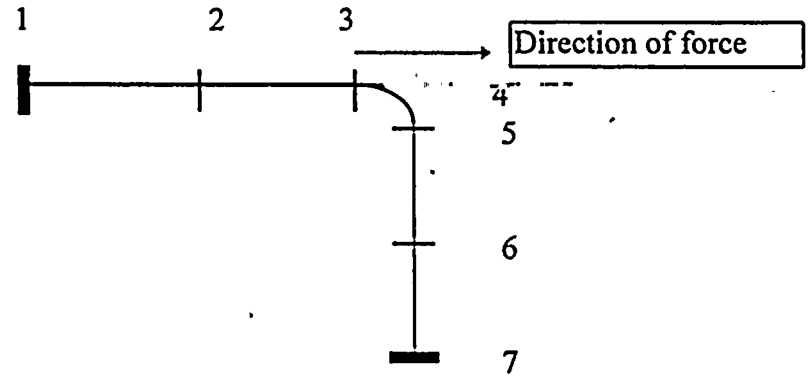
Time μ sec.	Force lbf
0	0
2	0
3	2550 x A
303	2550 x A
503	0
600	0

Where the A is pipe cross sectional area.

The time force history for the two cases modeled is shown below.



The piping elbow was modeled using the GE piping stress analysis computer program. The model is a simple L shape elbow for both pipe sizes with seven nodes as shown below.



Node numbers 1 and 7 are anchor points. The distance from node 1 to node 3 and from node 5 to node 7 are both 200 inches. The impulse time force history is applied at node 3, where the long radius elbow connects to the pipe for both the 8-inch and 4-inch pipe. The piping model was confined to the vicinity of the elbow. Conservatively, the analysis does not include effect of friction from the pipe wall, and the load is a fully developed force that occurs when the pipe length-to-diameter ratio (L/D) is >7. The result of the analysis shows the highest calculated moment occurs at the elbow-to-pipe location, node number 5. For 8-inch pipe, the calculated load is 93,395 lbf-in and for 4-inch pipe is 22,533 lbf-in. The combined stress, including impulse loading, hoop stress, and weight, is 10,520 psi for 8-inch pipe and 6441 psi for 4-inch pipe. Both stresses are well below the B31.1 allowable stress limit of 1.2 S_h (18,000 psi). Note that the hoop stress term ($P_0D_0/4t$) included in the above combined stress calculation was based on a pipe design pressure of 300 psia.

4. Results and Conclusions

The calculated results, as summarized below, show that the combined pipe stresses resulting from bending moment, pipe weight, and hoop stress from a detonation event in the Susquehanna Steam Electric Station offgas system piping are well within the B31.1 allowable limit, even when using very conservative analysis assumptions. This is the expected result based on previous history for detonations within BWR offgas piping. No piping failures have ever occurred as a result of these events, even though the systems had no special provisions for additional supports to limit potential bending moments. Based on this analysis, it is concluded that the Susquehanna offgas piping has sufficient design margin to sustain multiple detonation events without exceeding B31.1 allowable stress limits.

Summary of Analysis

Case	Calculated Stress	Allowable Stress	Percent of Code Allowable
8- inch pipe	10,520 psi	18,000 psi	58%
4-inch pipe	6441 psi	18,000 psi	36%

5. References

1. R.A. Head, GE document number GE-NE-B13-01920-48, Rev. 2 "Evaluation of Susquehanna Offgas System Pressure Integrity for Hydrogen Detonation", April 13, 1998.
2. P.M. Ordin, "Hydrogen-Oxygen Explosions in Exhaust Ducting", National Advisory Committee for Aeronautics Technical Note 3935, April 1957.
3. D.H. Edwards, et.al., "Pressure and Velocity Measurements on Detonation Waves in Hydrogen-Oxygen Mixtures", Fluid Mechanics, vol. 6, 1959.
4. D.B White, "On the Existence of Higher than Normal Detonation Pressures", GE Research Laboratory, Journal of Fluid Mechanics, Vol. 2, Part 5, p513, July 1957.