UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

Enclosure 1

SAFETY EVALUATION BY THE

OFFICE OF NUCLEAR REACTOR REGULATION

FLAW INDICATION IN A MAIN STEAM LINE

AT CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT 1

1.0 BACKGROUND

In Reference 1, Baltimore Gas and Electric Company (BG&E or licensee) reported the discovery of a flaw in a main steam line consisting of a smaller wall thickness than allowed by the original construction code, ANSI B31.1-1967. To justify continuing operation until the next refueling outage (March 1988) BG&E requested the use of ASME Code Section XI, IWB-3600, 1983 Edition, S83, which provides for an analytical evaluation of the flaw to determine its acceptability for continuing operation.

The licensee performed this evaluation and showed that all relevant criteria were met, except for IWB-3610(b). This section requires that the primary stress limits, which determine the minimum wall thickness be met. The licensee performed an evaluation of the primary stresses per B31.1, 1967, and ASME Code Case 1606, in the vicinity of the flaw and determined that the primary longitudinal stress limit was met, but the primary hoop stress limit was not met. The licensee requested relief from this requirement until the next refueling outage at which time he committed to satisfy all applicable requirements of ASME Code Section, IWB-3600.

The staff granted the requested relief on the following basis: 1) the affected pipe retained adequate fracture toughness, 2) a limit load analysis showed that there is sufficient wall thickness to prevent yielding, 3) the affected pipe was to be replaced or repaired at the next refueling outage (March 1988), and 4) the affected pipe was an isolated case. This basis was documented in References 2 and 3. In Reference 4, BG&E submitted a request to void the requirement that the flawed pipe section should be either repaired or replaced. This request was based on a refined stress analysis of the thinned wall section and a fracture mechanics evaluation, both of which are necessary to satisfy the requirements of IWB-3610 of Section XI. The fracture mechanics approach was previously shown to be acceptable (Reference 3) for the time period until the refueling outage. The fracture mechanics analysis was withdrawn (Reference 7) based on the final results of the finite element analysis which is the basis to demonstrate that the intent of the original construction code is met.

2.0 EVALUATION

In References 4 through 6, the licensee submitted the results of a finite element analysis of the thinned wall region of the No. 12 steam generator main steam line. The thinned wall region occurs at the butt weld intersection of a horizontal straight pipe of 34 in. OD with a 90° long radius elbow, and

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consists of a thin band approximately one-half of an inch wide and 24 inches long, located close to the elbow extrados. The smallest wall thickness in this band measured approximately .86 inches. This average wall thickness of the regular pipe was taken at 1.075 inches, and this was also assumed for the elbow.

A four foot segment of the straight pipe and the entire 90° elbow including the thinned wall region at the intersection were modeled with quadrilateral shell elements using the finite element computer program ANSYS. This program is acceptable per requirements in SRP 3.9.1, 1981. These elements possess membrane and bending capability and may have constant or varying thickness. The licensee modeled the thinned wall region and the adjacent pipe walls with shell elements of span-to-depth ratio of one-to-four. In ordinary application of such elements the recommended minimum span-to-depth ratio is about four-to-one. The effect on the accuracy of the calculated stresses of such a small span-to-depth ratio is unclear, but are not believed to be significantly different from those obtained from a model based on three-dimensional solid finite elements. Therefore, based on our judgment we find the application of such shell elements marginally acceptable in the present analysis.

The model was subjected to the internal design pressure (1000 psig) and piping bending moments due to dead weight loading. The intent of this analysis was to demonstrate that the thin walled region meets the primary membrane stress limit of B3.1, 1967, in both the hoop and the longitudinal directions when subjected to primary loading. The longitudinal stresses due to OBE, SSE and Steam Hammer were shown in Reference 1 to be well within the allowable stress for membrane plus bending.

The results of the calculations indicate that the maximum middle surface hoop stress in the thinned wall, which is also the maximum hoop membrane stress, was determined as 15,874 psi. The maximum bending plus membrane hoop stresses were calculated as 14,158 psi on the outside surface and 19,615 psi on the inside surface, at different locations on the wall. The maximum longitudinal membrane stress was calculated at 8,673 psi, while the maximum longitudinal bending plus membrane stresses were calculated as 7,421 psi on the outside surface and 11,374 psi on the inside surface, at different locations on the wall. The bending stresses in both the hoop and the longitudinal directions are considered as local effects. The primary membrane stress limit for the pipe material was determined as 17,500 psi, and the primary membrane stresses are thus shown to satisfy these limits. The membrane hoop stress, based on the minimum wall thickness in the flaw and the simplified method of B31.1, 1967, was calculated as 19,383 psi which exceeds the primary membrane stress limit.

According to the Foreword of the Code, "a designer who is capable of a more rigorous analysis than is specified in the Code may justify a less conservative design, and still satisfy the intent of the Code." The finite element analysis reported in Reference 4 represents a more rigorous analysis than the procedure in B31.1 specified for determining the minimum wall thickness required to contain the specified design pressure.

3. CONCLUSION

Based on our evaluation, we conclude that although the measured wall thickness in the flaw is smaller than the required wall thickness, it does satisfy the intent of the Code, and is acceptable. Therefore, we also conclude that the requirements of IWB-3610(b) of ASME Code Section XI are also satisfied. However, because of the size and location of the flaw we note that BG&E is subjecting the flawed portion of the pipe to non-destructive examination at a minimum of every refueling outage. We consider this to be prudent based on the following: the flaw is one-half of an inch wide by 24 inch long band, and is .22 inch (approximately one-fourth of an inch) deep in a 1.075 (approximately 1-1/16 inch) pipe wall. It is located along the circumference near the extrados of the pipe/elbow weld, and may therefore, be susceptible to erosion/corrosion effects due to a variety of flow phenomena which exist in or near pipe bends (Reference 8).

Principal Reviewer: M. Hartzman

REFERENCE

1. Letter from A. R. Thornton, BG&E, to A. C. Thadani, NRC dated December 16, 1986.

2. Memo from D. M. Crutchfield to Scott McNeil, dated February 9, 1987.

3. Letter from A. C. Thadani, NRC, to J. A. Tierman, BG&E, dated March 26, 1987.

4. Letter from J. A. Thierman, BG&E, to NRC Document Control Desk, dated September 30, 1987.

5. Letter from W. J. Lippold, BG&E, to NRC Document Control Desk, dated May 4, 1988.

6. Letter from S. R. Cowne, BG&E, to NRC Document Control Desk, dated June 6, 1988.

7. Letter from G. C. Creel, BG&E, to NRC Document Control Desk, dated April 13, 1990.

8. IE Information Notice No. 86-106, Supplement 1, "Feedwater Line Break," February 13, 1987, page 4.