UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION REPORT

ONCE-THROUGH STEAM GENERATOR REPAIR AND AUXILIARY FEEDWATER SYSTEM MODIFICATIONS

SACRAMENTO MUNICIPAL UTILITY DISTRICT

RANCHO SECO NUCLEAR GENERATING STATION

DOCKET NO. 50-312

1.0 Introduction

In April 1982, the steam generator (SG) internal auxiliary feedwater (AFW) headers at Davis-Besse 1 were discovered to be damaged. Accordingly, on April 19, 1982, inspections of the internal SG AFW headers were begun at the Rancho Seco facility (the facility was already shutdown for high pressure injection nozzle repairs). The internal headers were found to be in a condition similar to that found at Davis-Besse 1. The outer surface of the headers were concave and uneven, the header supports were deformed, and one header support pin in each SG was missing.

The licensee has disconnected the damaged internal feedwater header and securely fastened the header in place. Additionally, the AFW injection system has been modified to incorporate an AFW injection system external to the SGs.

This SER evaluates the acceptability of the above modifications and corrective actions.

2.0 Discussion

By letters dated May 20, 1982 and August 3, 1982, the Sacramento Municipal Utility District (SMUD) submitted information related to: (1) the repairs of the damaged internal AFW headers and (2) the modifications made to the AFW system. Supplemental information was submitted by SMUD letters dated August 16, 17 and 18, 1982.

The repair and modification program selected by SMUD consisted of: (1) modifying the AFW injection system and (2) disconnecting and securely fastening the retired internal header to the steam shroud.

The design uses an external header fabricated of 6 inch diameter pipe which encircles the steam generator shell for about 300 degrees. Six 3-inch diameter pipe risers, spaced around the ring, feed AFW through the steam generator shell and shroud to the secondary side of the tubes. To allow for injection of AFW into the steam generator, it was necessary to bore six 5-inch diameter holes through the steam generator shell. The same size hole was bored through the shroud, in line with the hole in the shell. The pipe risers are flanged and bolted to the shell.

The centerline of the riser inlet to the steam generator will be located about 14 inches above the top tube support plate. A tapered thermal sleeve will direct the flow from the shell opening through the shroud to the steam generator secondary side. Each riser will contain an orifice at the flange in the vertical run to help equalize distribution of flow.

This design is similar to that used at five operating B&W plants except that 1) the point of injection of AFW is approximately 3 inches higher than in the earlier designs, 2) the Rancho Seco modification uses orifices in the risers, and 3) the feed to the risers in the Rancho Seco modification is nearer the midpoint of the external header.

The damaged internal header has been solidly secured in place to continue to function as an extension of the tube bundle shroud; however, it will no longer function as part of the AFW system. At six locations around the circumference, corresponding to the location of the 5 inch holes bored into the steam generator shell, the bottom of the internal header has been secured to the shroud with a 7-inch long fillet weld. Additional support has been added at these locations using gusset plates welded to the shroud and the bottom of the header. The original nozzle, which used to deliver AFW to the internal header, is blocked with a blind flange.

Access to the internal AFW header, header supports and feedwater nozzle is through one 16 inch access port and the six 5 inch holes bored through the shell and shroud. Because of this limited access, only a small portion of the header could be inspected by direct visual means. Most of the inspections were done using remotely operated video cameras and fiber optic devices.

Inspection of the damaged internal AFW header system revealed that a number of the header support brackets were deformed, and many of the dowel pins were out of position. All loose parts have been removed from the steam generator.

All critical areas of the header, header supports, AFW nozzle, and steam generator shell have been inspected by one or more methods except for the inner corner welds of the internal header. The inspection techniques used were:

1) Limited direct visual
2) Remote video with 3 to 5 times magnification
3) Fiber optics with 3 to 5 times magnification
4) Ultrasonic (UT)
5) Dye Penetrant (PT).

Only about 20% of the inner corner welds of the header could be inspected. These weld areas were inspected using fiber optics.

The inspections of the critical areas revealed a 20" crack on the lower inner weld in "A" steam generator and a 15" crack on the lower inner weld in "B" steam generator.

3.0 Evaluation

3.1 Cause for Header Damage

The licensee has considered several mechanisms as the possible cause of the deformation of the internal headers, but has concluded that the most likely cause is rapid condensation-induced high pressure differental. Stress calculations performed by the licensee concluded that a pressure differential in excess of 200 psi is required to cause collapse of the internal headers. We agree with the licensee's assessment that rapid condensation-induced pressure differential is most likely the cause of the collapse.

The design of the internal AFW header was such that during operation of the plant, prior to AFW actuation, the header would be filled with steam. When AFW is actuated, there would be flow of subcooled water which would result in a rapid condensation of trapped steam, with attendant depressurization, inside the header. We also conclude that the rapid flooding of the header with cold AFW when the steam generator is at operating conditions produces high thermal stress which could contribute to the distortion.

The modified AFW system is similar in design to systems used at five other B&W operating plants that have more than 22 reactor years of operation without any evidence of water hammer or condensation induced pressure surges. Additionally, the modified AFW risers and external header will not be insulated, to promote steam condensation, to insure that the risers and header ring will remain filled with water.

The external AFW header will facilitate visual inspection of the AFW piping and thereby permit identification of any damage due to rapid condensation induced high differential pressure.

The licensee's August 3, 1982 submittal provided responses to the staff's request for additional information, which was dated June 23, 1982. Item 11 of the staff's June 23 letter requested a description of the water hammer test to be performed prior to resumption of power operation. In the licensee's submittal dated August 18, 1982, the licensee committed to perform a water hammer test before criticality. Therefore, with respect to the dynamic effect associated with possible fluid flow instabilities, the requirements and guidelines of the following documents have been met: General Design Criterion 4, "Environmental and Missile Design Bases", NUREG-0800, Standard Review Plan, Section 10.4.7, "Condensate and Feedwater System" and Branch Technical Position ASB 10-2, "Design Guidelines for Water Hammers in Steam Generators with Top Feedring Design".

3.2 Modified AFW System

As previously stated, the modified AFW system is similar to designs which have been in service for 22 reactor years. The proposed design differs from the inservice design in two respects: slightly higher elevation of AFW injection and use of flow equalizing orifices. The latter feature will result in a higher AFW flow resistance. In a submittal dated August 18, 1982, the licensee agreed to perform a hot AFW flow test to verify that the minimum required flow is provided to the steam generators. The staff has concluded that the modified AFW system is acceptable. This conclusion is based on:

(1) the similarity of the modified AFW system to proven designs,
(2) verification of required minimum AFW flow, and,
(3) the performance of a water hammer test.

3.3 Internal Header Stabilization

The extensive internal header inspection program carried out for Rancho Seco shows about the same type of damage that was discovered at Davis-Besse and Oconee 3. Namely, the vertical wall of the header was distorted inwards towards the center of the steam generator, the support brackets were bent or damaged and some dowel pins were either out of position or missing. As a result of this distortion, the distance between some peripheral tubes and the header had been reduced.

The inspections performed on the Rancho Seco AFW headers revealed two cracks in the header corner welds. One is approximately 20 inches long in "A" steam generator and the other is 15 inches long in the "B" steam generator. Both cracks were located in the lower inside weld which joins the inner plate to the bottom of the internal header of the steam generators.

For the Oconee plant, in addition to the previously described typical damage, extensive additional damage also was observed in the "B" steam generator. This additional damage consists of many cracks in the attachment welds and three holes in the horizontal plates of the internal header. For the Davis-Besse plant, the previously described typical damage was found, but cracking of the corner welds of the header was not identified.

In order to prove the adequacy of the stabilized header, its associated welds, and support and attachment system, the licensee has performed a three dimensional analysis where the stabilized header was modeled using the ANSYS Finite Element Code. The shroud was also modeled along with the shroud alignment pins. The analysis was performed for the appropriate load combinations of deadweight, flow induced vibration, operating basis earthquake, thermal transients, safe shutdown earthquake LOCA, and main steam line break. It was shown from the results of the analysis that the load combination of Level D (Faulted) loads which includes the main steam line break and safe shutdown earthquake is the limiting case for the header weld analysis. Even in this limiting case, a factor of safety of 2.2 over ASME Section III code allowable stresses is obtained. This can be interpreted to mean that only 45.5% of the weld would be required to insure the structural integrity of the header provided that any damage in the weld is evenly distributed in the circumferential direction. Another analysis has been performed using the load combination of the limiting case assuming a 28 inch crack to exist in the lower inner corner weld of the header to determine its effects on the header stress pattern. The results of the analysis show that the crack does cause a slight increase on the local stresses but has no impact on the function of the header. Moreover, the largest loading on the corner weld is a moment about the tangential axis due to differential thermal expansion. Thus, the potential for crack propagation will be in the radial direction, i.e., through the wall, and not in the circumferential direction.

SMUD has performed an analysis to demonstrate the adequacy of the distance between the header and steam tube bundle. It was shown that for the limiting case the distance is adequate to preclude damage to tubes which are no closer than the minimum distance, and that substantial margin still exists to preclude any rupture in the tubes. Furthermore, SMUD's August 3, 1982 letter provides a commitment to inspect the stabilized internal header, the attachment welds and external header thermal sleeves through all AFW injection openings during the next two refueling outages and at the ten year inservice inspecton intervals.

Based on the results of the analysis performed for the stabilized internal header, the margin of safety associated with all loading combinations postulated to occur, including an assumed crack of 28 inches, the inservice inspection carried out at each plant, and the future inservice inspection program planned for the secured header, the staff has concluded that the internal AFW header stabilization is acceptable.

3.4 Loose Parts

All loose parts have been located and removed from both steam generators.

4.0 Conclusion

We have concluded, based on the considerations discussed above, that: (1) because the facility modifications do not involve a significant increase in the probability or consequences of an accident previously evaluated, does not create the possibility of an accident of a type different from any evaluated previously, and does not involve a significant reduction in a margin of safety, the facility modifications do not involve a significant hazards consideration, (2) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and (3) such activities will be conducted in compliance with the Commission's regulations and will not be inimical to the common defense and security or to the health and safety of the public.

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The following NRC personnel have contributed to this Safety Evaluation:
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