TECHNICAL EVALUATION REPORT

ON

BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2

TASK NOS. 90 AND 91

TAC NOS. 08211 AND 08212

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TECHNICAL EVALUATION REPORT

UNIT: BRUNSWICK STEAM ELECTRIC PLANT UNITS 1 AND 2

LICENSEE: CAROLINA POWER AND LIGHT CO.

DOCKET NOS: 50-324/50-325

TAC NOS. 08211/08212

1. INTRODUCTION

The purpose of the ultrasonic inspections was to examine the recirculation inlet nozzle safe ends in Brunswick Units 1 and 2 for potential intergranular stress corrosion cracking (IGSCC). The concern arose because large intergranular stress corrosion cracks were found in the safe ends at the Duane Arnold Electric Center (DAEC) which resulted in leakage in June 1978.(2)* The joint design and materials used at Brunswick Units 1 and 2 are similar. A thermal sleeve is welded into each safe end which carries the recirculation flow to the jet pump risers. The safe ends and thermal sleeves are fabricated from Inconel 600. The design results in a long, narrow crevice adjacent to the attachment weld. The crevice is conducive to the creation of an oxygen concentration cell. Also, the welding produces a sensitized, heat-affected zone and high local stresses. However, significant differences in stress levels, wall thickness, welding techniques, and operating conditions exist between DAEC and Brunswick Units 1 and 2.(11) For these reasons Brunswick safe ends have a significantly lower probability of IGSCC occurrence than the original DAEC safe end design.

The leaking safe end and the other seven safe ends at DAEC were examined by UT. All eight safe ends showed indications large enough to be considered rejectable. All eight safe ends were replaced. Subsequently, a more detailed examination showed that all safe ends were cracked, with cracks extending almost completely around the circumference.

The leaking safe end from recirculation inlet nozzle N2A was submitted to Southwest Research Institute for a thorough metallurgical investigation to establish the nature and extent of the cracking and to identify the mechanism and cause of failure.(8) Crack penetration of the safe end wall had occurred over approximately 85 degrees of the outside surface. The investigation included

* Numbers in parentheses refer to the list of criteria supplied to FRC.

ultrasonic testing, chemical analysis, metallographic examination, and fractographic examination. The results of the investigation indicated:

1. Significant cracking occurred on the inside surface over the full 360° of circumference.

2. The cracking was completely intergranular.

3. All cracking initiated in the immediate vicinity of the tip of the tight crevice between the thermal sleeve and the safe end.

4. Crack initiation and the early stages of crack propagation occurred within the heat-affected zone of the thermal sleeve attachment weld.

5. The chemical composition of the safe end and the thermal sleeve conformed to the specification.

6. The chemical composition of the deposited weld metal conformed to the specification except for a minor variation in Manganese content.

7. The repair weld on the outside of the safe end was not a factor in the initiation or propagation of IGSCC.

On the basis of reported data, IGSCC of Inconel 600 is not likely unless stresses exceed the yield strength. The effect of sensitization on IGSCC has not been completely resolved although it is significant that cracking initiated in the heat-affected zone of the welds. It has been demonstrated that the presence of a crevice significantly accelerates cracking in low pH and high oxygen content solutions, and General Electric data indicate that crevices enhance the susceptibility to IGSCC in BWR environments. In view of these factors, it is likely that the presence of the crevice was a principal contributing factor in the cracking.

The fact that multiple cracking was not observed along the crevice is significant. Several factors, including microstructural gradients, stress distribution, and variation of the corrosive environment in the crevice, apparently resulted in an optimum location for crack initiation which is not necessarily at the point of highest stress level.

2. CRITERIA PROVIDED BY THE NRC

The following is a list of documentation provided by the NRC and used by FRC for problem definition, background and evaluation criteria:

1. NUREG 0312

2. NUREG 0531

3. Letter, E. E. Ultey, CP&L to T. A. Ippolito, NRC, dated February 21, 1979, Results of Inspection of Safe Ends.

4. Letter, J. H. Smith, ORNL, to V. Stello, NRC, dated February 23, 1979, Review of UT Inspection of Safe Ends.

5. Letter, J. H. Gieske, Sandia, to V. Stello, NRC, dated February 5, 1979, Review of UT Inspection of Safe Ends.

6. Letter, E. E. Utley, CP&L to T. A. Ippolito, NRC, dated April 17, 1979, Results of Inspection of Safe Ends.

7. Letter E. E. Utley, CP&L to T. A. Ippolito, NRC, dated December 22, 1978, Inspection Program for Safe Ends.

8. Metallurgical Investigation of Cracking in a Reactor Vessel Nozzle Safe End by Southwest Research Institute, Report on Safe End Cracking at Duane Arnold.

9. Memo, R. C. Heishman, NRC to R. W. Woodward, NRC, dated September 13, 1978, Discussion of Duane Arnold Safe End Cracking.

10. Letter, T. A. Ippolito, NRC to Duane Arnold, dated January 8, 1979, Discussion of Duane Arnold Modified Safe Ends.

11. Letter, E. C. Utley, CP&L, to T. A. Ippolito, NRC, dated December 8, 1978, Inspection Results of Safe Ends.

12. Memo, J. N. Hannon, NRC, to T. A. Ippolito, NRC, dated December 8, 1978, Discussion of Brunswick Safe Ends.

13. Results of Ultrasonic Testing of Reactor Recirculation Safe Ends in Accordance with Lambert, MacGill, Thomas Procedure UT-10. Undated, Results of Brunswick Inspection.

3. TECHNICAL EVALUATION

3.1 BRUNSWICK UNIT 1

The recirculation inlet nozzle safe ends in Brunswick Unit 1 were UT inspected in September 1978. No reportable indications were noted; however, several small suspect areas were found.(4) Four safe ends were reinspected in November 1978 with inconclusive results. Therefore, another inspection of all 10 safe ends was conducted in January 1979. Evaluation of all the data from the three inspections indicated that sufficient evidence was not available to positively determine whether a crack actually existed in any of the 10 safe ends. The largest indication in UT examination was found in the safe end of nozzle N2D, between the 9 and 12 o'clock locations on scan 4, zone 2. The amplitude of this indication was measured at 78 percent of DAC in September 1978 and 80 percent of DAC in

January 1979.(4) These measurements indicate good correlation of data. A reflector measured at about 33 percent of DAC was noted in N2E, with smaller indications in other nozzles. The correlation between the indications measured in September 1978 and January 1979 demonstrated that rapid flaw growth was not occurring and that the safe ends were satisfactory for continued operation.

3.2 BRUNSWICK UNIT 2

The safe ends in Brunswick Unit 2 were also UT inspected in September 1978. Another inspection in March 1979 showed no appreciable change in the data. All of the indications were small (maximum measurements were recorded as 20 percent DAC) and were possibly the result of internal nozzle geometry. These safe ends are also considered satisfactory for continued operation.

A review of all data from Duane Arnold and Brunswick Units 1 and 2 indicated that the geometry of the thermal sleeve-to-safe end weld may result in UT indications from sources which are not metallurgical discontinuities in the material. Reflections were noted at the attachment weld where a small crevice exists. Assuming a discontinuity does exist in the weld heat-affected zone, this area is a possible location for crack initiation and propagation. Therefore, a program for monitoring these locations is advisable.

Further information regarding this particular problem can be found in NUREG 0531. This document states that for plants with thermal sleeve-to-safe end attachment welds forming crevises, an inservice inspection program should be developed to examine the attachment weld and surrounding material to assure that cracking does not develop undetected during service. NUREG 0313 provides recommendations for an inspection program for nonconforming service-sensitive lines.

4. CONCLUSION

Ultrasonic examination of recirculation inlet nozzle safe ends in Brunswick Units 1 and 2 were conducted during September 1978. No reportable indications were detected; however, several suspect areas were found which were judged to be either reflections due to the geometry of the thermal sleeve-to-safe end weld area or the existence of small discontinuities. Subsequent UT inspections of Brunswick Unit 1 in January 1979 and Unit 2 in March 1979 indicated that no significant change in ultrasonic response was detected. Based on the short time interval between the two inspections, it was concluded that, if flaws were indeed present in the safe ends, rapid growth had not occurred and that the recirculation safe ends are satisfactory for continued operation. In order to ensure the continued integrity of the safe ends, the licensee should develop an inspection program to continue the monitoring of safe ends, particularly in the suspect weld areas.

If flaw growth is indicated on future inspections, consideration should be given to installation of the new-design thermal sleeve used in the Duane Arnold unit. This design has virtually eliminated the crevice and relocated the weld so that cracking in the heat-affected zone will not affect the pressure boundary integrity of the reactor.