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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATING TO INSPECTIONS AND REPAIRS OF

INTERGRANULAR STRESS CORROSION CRACKING (IGSCC)

BRUNSWICK STEAM ELECTRIC PLANT, UNIT 1

CAROLINA POWER & LIGHT COMPANY

DOCKET NO. 50-325

1.0 INTRODUCTION

The staff has reviewed the licensee's (CP&L) submittals dated July 18 and December 28, 1988, and January 13 and 27, February 20, March 14, May 6 and June 28, 1989, regarding the intergranular stress corrosion cracking (IGSCC) inspection results, mitigation, flaw evaluations and overlay repairs to support the continued operation of Brunswick Steam Electric Plant, Unit 1 (Brunswick Unit 1), in its present configuration for an 18-month fuel cycle. During the Brunswick Unit 1 refueling outage 6, 92 welds, including 16 Inconel 182 buttered nozzle welds and 10 recirculation inlet safe-end thermal sleeve attachment welds, were ultrasonically examined.

The results of the inspection showed that flaw indications were found in 9 nozzle to safe-end welds (7 recirculation riser nozzles and 2 core spray nozzles, and 10 recirculation riser thermal sleeve to safe-end attachment welds. All flawed welds were reinforced with either standard or limited service weld overlays. The mechanical stress improvement process (MSIP) was applied to seven Inconel 182 buttered nozzle welds as a mitigation for IGSCC. During this refueling outage, the remaining portion of the reactor water clean-up (RWCU) system piping susceptible to IGSCC was replaced with a low carbon stainless steel material (316L). Because of extensive IGSCC being found in the recirculation inlet riser piping system, the licensee has committed to replace the riser piping and the safe-ends during the Brunswick Unit 1 1990 refueling outage.

2.0 DISCUSSION

Inspection

The licensee reported that there are 266 welds subject to IGSCC inspection in Brunswick Unit 1. These welds are located in the recirculation system, residual heat removal (RHR) system, RWCU system, core spray system and the jet pump instrumentation penetration assemblies. 92 welds were inspected during this refueling outage, which included 16 Inconel 182 buttered nozzle welds, 10 riser thermal sleeve-to-safe end attachment welds, 18 overlay repaired welds and one unrepaired weld. The original sample size required an inspection of 77 welds which was expanded to 92 welds after flaw-like indications were found in the original samples. The staff concludes that the scope of IGSCC inspection meets the staff requirements and the guidelines in Generic Letter 88-01. The staff also concludes that the limited sample expansion is acceptable because all of the welds with configuration similar to the welds found flawed during this outage were inspected.

Ultrasonic Examination

The licensee reported that the IGSCC inspection was performed by General Electric Company (GE) personnel qualified at EPRI NDE Center. These examiners also passed the latest requalification program. The fully automated GE "SMART" ultrasonic testing (UT) system was used for examination, where geometrically feasible. The automatic system utilizes the Ultra Image III computer-driven data acquisition system with the ALARA remote scanning device. Manual examinations were performed where automatic UT could not be performed or to supplement the SMART UT examination.

During this outage, flaw indications were found in nine nozzle to safe-end welds with seven in the 12-inch inlet recirculation piping system (12AR-A6, 12AR-B6, 12AR-C6, 12AR-D6, 12AR-E6, 12BR-G6 and 12BR-H6) and two in 10-inch core spray piping system (N5A and N5B), and all 10 recirculation riser thermal sleeve to safe-end attachment welds. All flawed welds were overlay repaired. Except for core spray weld N5B, short axial flaws, varying in depth from 30% to 82% of through-wall thickness were reported in flawed nozzle to safe-end welds. The deepest axial flaw with 82% of through-wall thickness was reported in recirculation weld 12AR-D6. A circumferential flaw with a length of 2.3 inches and a maximum depth of 60% of through-wall thickness was found in core spray N5B weld. The UT data indicated that all the flaws in the nozzle to safe-end welds were initiated from the Inconel 182 nozzle butter, which was post-weld heat treated, and all the axial flaws in the butter appeared to penetrate a short distance into the low alloy steel nozzle material.

Numerous axial and circumferential flaws were reported in the alloy 600 safe-ends near the thermal sleeve attachment welds. These flaws were detected by using longitudinal refractive waves. These thermal sleeve attachment welds were previously examined using shear waves and no flaws were found. The maximum depth of axial and circumferential flaws were reported to be 65% and 70% through-wall thickness, respectively. Five thermal sleeve attachment welds were reported to have circumferential indications 360 degrees all around. The staff notes that the configuration of the thermal sleeve at Brunswick Unit 1 has a crevice condition at the attachment weld location. The crevice condition is known to promote IGSCC. The licensee indicated that these flaws were not detected earlier because proper techniques were not used in previous examinations. A metallurgical boat sample was removed from the safe-end of the recirculation inlet nozzle N2D to confirm the reported flaw indications. Although flaws were not found in the boat sample, the occurrence of leakage at the location where boat sample was removed confirmed the presence of flaws.

An unrepaired recirculation elbow-to-valve weld (28A8) was re-examined during this outage. The inspection results showed that the existing flaws did not have significant changes in sizes from previous examinations. This weld was mitigated with the mechanical stress improvement process (MSIP) during refueling outage 4.

Eighteen previously repaired overlays welds were examined during this outage. Several small flaws not previously recorded were found in three overlay repaired welds (12BRK4, 12BRJ3 and 12BRJ2). The licensee indicated that the probable reason for detecting those additional flaws during this outage was the use of improved techniques and equipment, as well as better trained personnel.

Flaw Evaluation

Some flaw indications characteristic of a lack of fusion or bonding were found in nine overlays applied to inlet nozzle to safe-end welds during this outage. Structural Integrity Associates (SIA) performed flaw evaluation for the licensee in accordance with the requirements of ASME Code, Section XI. The results of the evaluation have shown that those flaws are acceptable without repair. The post-overlay UT examinations also reported apparent growth of existing flaws in two recirculation inlet nozzles (D and H) as a result of overlay repair. The nozzle side of the overlay was machined down for additional UT examination. The additional UT examination shows that the growth of these existing flaws did not extend into the overlay or beyond the repaired area. Therefore, no further repair of inlet nozzles D and H is needed.

The staff concludes that these flaw evaluations are acceptable.

Weld Overlay Repair

During this outage, 19 welds were overlay repaired with the standard design applied to nine nozzle to safe-end the welds and limited service design was applied to 10 recirculation inlet safe-end thermal sleeve attachment welds. SIA performed the overlay design for the licensee. The licensee reported that the as-built thickness and length of each overlay meets the minimum designed dimensions. SIA has evaluated the weld overlay induced shrinkage stresses in the recirculation piping systems as a result of 49 weld overlay repairs. The largest shrinkage stress on unflawed welds was reported to be 12.21 ksi on weld 12-BR-F6, which is within the ASME Code allowable limit. The shrinkage stress at the unrepaired weld 28-A8 is reported to be small (560 psi).

A composite Inconel (alloy 82) weld overlay was applied to seven 12-inch recirculation inlet nozzle to safe-end welds and two core spray nozzle to safe-end welds. The downstream side of the overlay was extended into the nozzle for covering the flaw in the nozzle butter. The first three layers (minimum) of the overlay adjacent to the nozzle were deposited using a qualified Inconel temper bead technique with no water in the piping. The remaining portion of the overlay was fabricated using the normal overlay repair technique with water running in the piping. The Inconel temper bead technique was developed by EPRI in accordance with the requirements in ASME Code, Section XI, and Code Case N-432 for weld overlay repair of P-3 components to preclude the post-weld heat treatment. Mechanical testing, including tensile, bending, hardness and toughness tests, was performed on a 12-inch nozzle mock-up. The mechanical properties of the mock-up nozzle after Inconel weld overlay repair was reported to meet the Code requirements.

The staff concludes that the weld overlay repairs performed during this outage are acceptable.

Mechanical Stress Improvement Process (MSIP)

O'Donnel and Associates, Inc. (ODAI) successfully performed MSIP for the licensee on seven Inconel buttered nozzle to safe-end welds including two 28-inch recirculation outlet nozzle welds, three 12-inch recirculation inlet nozzle welds and two 4-inch jet pump instrumentation (JPI) nozzle welds. MSIP is a mechanical process that replaces the tensile residual stresses on the inside surface of the weldment with a zone of compressive residual stresses. The effectiveness of the MSIP applied to different sizes of nozzle welds was analytically verified by ODAI using a non-linear finite element analysis of the process. It was shown that the permanent strain induced by MSIP in the range of 0.5% to 1.19% is adequate to produce the desired redistribution of the residual stresses. The ultrasonic examination was performed before and after the application of MSIP to ensure the integrity of each treated weld.

Because the distribution of the residual stresses resulting from the subject MSIP applications was not confirmed experimentally on a mock-up, the staff has some reservations regarding the effectiveness of these applications and its effect on the adjacent thermal sleeve attachment weld. To ensure that the subject applications are reliable and effective, additional laboratory testing should be considered, such as measuring the residual stresses and performing component testing to confirm its effectiveness in mitigating the IGSCC.

Piping Replacement

The licensee reported that during this refueling outage the remaining portion of the RWCU system piping susceptible to IGSCC was replaced with low carbon austenitic stainless steel materials. The licensee also indicated in their submittal dated June 28, 1989, that the Brunswick Unit 1 inlet riser piping and safe-ends in the recirculation system will be replaced during the 1990 refueling outage.

Special Surveillance Measures

The licensee indicated that special surveillance measures for unidentified leakage will continue to be implemented at the Brunswick Unit 1 plant. The staff finds that these special surveillance measures are consistent with the guidelines in Generic Letter 88-01.

3.0 Conclusion

Based on our review of the licensee's submittals, the staff concludes that the licensee has adequately addressed IGSCC in Class 1 piping with respect to inspections, repairs and mitigations performed during the Brunswick Unit 1 refueling 6 outage, and that these activities were performed in accordance with the guidelines in Generic Letter 88-01. In addition, the staff also concludes that Brunswick Unit 1 can be safely operated for an 18-month fuel cycle in its present configuration.

Dated:

Principal Contributor: W. Koo

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