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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO INTERGRANULAR STRESS CORROSION CRACKING

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT, UNIT 3

DOCKET NO. 50-296

1.0 INTRODUCTION

Browns Ferry Unit 3 was shut down on September 6, 1983 in accordance with a Confirmatory Order issued by the Commission on August 26, 1983. The Order required the Tennessee Valley Authority (the licensee) to inspect all ASME Class 1 austenitic stainless steel piping welds that are susceptible to intergranular stress corrosion cracking (IGSCC) in the Recirculation, Residual Heat Removal (RHR), Core Spray and Reactor Water Clean-up (RWCU) piping systems. Except for one RHR head spray weld which was subsequently removed, no IGSCC indications were found in welds of the above four piping systems. Thus, no repairs or evaluations as to acceptability were required.

As a result of cracks found in Monticello's jet pump instrumentation penetration seal welds, the licensee ultrasonically inspected all 10 welds in the components of the jet pump instrumentation penetration nozzles during the later stage of the outage. IGSCC cracks were found in the safe-end to reducer weld in both nozzles. This Safety Evaluation primarily addresses the repairs to the jet pump instrumentation nozzles.

A detailed discussion of all weld inspections is presented in the licensee's report of August 9, 1984.

To reduce the potential for IGSCC, the licensee used Induction Heating Stress Improvement (IHSI) to reduce the stresses in all welds on which this treatment could be implemented. A total of 148 welds were treated, as discussed in Attachment 5 of the licensee's August 9, 1984 report. The licensee is also evaluating significant improvements to the water chemistry program to reduce the third (and only other controllable) factor that affects stress corrosion cracking of the primary coolant piping. The programs being evaluated include use of hydrogen to reduce dissolved oxygen in the water, advanced analytical equipment and tighter control on the introduction and removal of impurities from the water. Altogether, the licensee's actions to detect and prevent possible IGSCC went well beyond what was required in the Confirmatory Order.

2.0 INSPECTION

Qualified ultrasonic testing (UT) personnel using the same procedures and techniques qualified under I&E Bulletin 83-02 were used in this inspection. Region II of the NRC has indicated that the inspections were conducted properly and met the staff and Code requirements. The results of the UT examinations indicated that two safe-end to reducer welds in the jet pump instrumentation penetration nozzle assemblies were cracked. The cracks were axially oriented and located intermittently around the circumference of the safe-end. Two pin-hole leaks were visually observed on one of the safe-end to reducer welds and were confirmed by liquid penetrant test. The worst axial crack indication is essentially through-wall over the thinnest portion of the safe-end and extends about 3.75 inches toward the nozzle weld. Based on a field metallographic examination using a replica technique, the safe-end materials were determined to be sensitized because a grain boundary "ditched" appearance was observed in the microstructures after an electrolytic oxalic acid etch.

3.0 REPAIR

The two cracked jet pump instrument nozzle safe-end to reducer welds were repaired by overlay. Structural Integrity Associates (SIA) performed the weld overlay design for the licensee. The weld overlay thickness was designed to meet the requirements of ASME Code, Section XI, IWB 3640. The required minimum overlay thickness was originally designed to be 0.18 inch and was increased to 0.25 inch to provide additional safety margin in response to concerns regarding the conservatism of the Code IWB 3640 Tables. The overlay design was based on a design pressure of 1250 psi and the worst axial crack with a length equals the full length of the safe-end (5.5 inches). The repair configuration consisted of multiple layers of weld overlay covering the entire safe-end and extending from the change-in-section region of the eccentric reducer to the center of the safe-end to nozzle weld. The repair started with one layer of shielded metal arc weld (SMAW) over the cracked region and one layer of gas tungsten arc weld (GTAW) over the entire safe-end. These two layers were applied with the pipe dry. After satisfactory completion of the liquid penetrant test of the repaired surface, four additional layers of GTAW were applied with water in the pipe. The minimum thickness of these four GTAW layers was designed to be 0.25 inch. Ultrasonic examinations were performed on the entire length of the weld overlay to ensure the structural and the bonding integrity of the overlay. The licensee indicated that the average "as-built" effective overlay thickness for the two repaired welds is 0.27 inch and 0.31 inch respectively. If the first two layers are included, the overall thickness of the overlay for the two repaired welds is approximately 0.40 inch and 0.45 inch, respectively. Region II has confirmed that the overlay repairs were performed in accordance with qualified and approved procedures consistent with the ASME Code requirements. The materials used for the weld overlay were low carbon stainless steel in accordance with staff guidelines.

4.0 EVALUATION

We have reviewed the licensee's submittals including SIA's weld overlay designs to support the continuing service of the two overlay repaired jet pump instrumentation penetration nozzle safe-end to reducer welds.

We reviewed the SIA's weld overlay design for the two defective safe-end to reducer welds in the jet pump instrumentation nozzle assemblies. SIA's overlay design is based on hoop stresses due to the design pressure (1250 psi) because the required overlay thickness is more limiting in considering axial cracks.

The conservatively designed minimum overlay thickness (0.25 inch) was shown to meet the ASME Code IWB 3640 limit with substantial margins. SIA also conservatively calculated the structural margins of the designed overlay by neglecting the load carrying capability of the original safe-end piping. The SIA's calculations have shown that the designed minimum overlay thickness alone is able to meet the ASME Code Section III allowable stress (Sm= 16,950 psi). We performed an independent calculation of the structural safety margins of the weld overlay by taking the credit of the thickness of the first two layers and using an operating pressure of 1100 psi. The calculated hoop stress in the overlay repaired piping is less than half of the Code allowable stress (Sm) which indicates the presence of a safety margin double that required by the Code. Therefore, we conclude that the SIA designed weld overlay for the defective safe-end to reducer welds is acceptable because the Code required safety margins would be maintained with substantial margins.

Peach Bottom Unit 2 is currently replacing its recirculation system piping. In August 1984, IGSCC was reported in several recirculation inlet nozzle safe-ends in the neighborhood of the thermal sleeve attachment welds. The cracked safe-ends were made of low carbon stainless steel. General Electric (GE) attributed the cracking to the presence of either cold-work on the safe-end inside surface or a crevice condition formed between the thermal sleeve and the safe-end, and assisted by the presence of the tensile residual stresses resulting from the fillet welding to attach the thermal sleeve to the safe-end. We noted that the design of the thermal sleeve in the recirculation inlet nozzles of Browns Ferry Units 2 and 3 is similar to that of Peach Bottom Unit 2. During the current Browns Ferry Unit 3 outage, the attachment weld areas of the recirculation inlet nozzle safe-ends were not inspected. The guidelines in NUREG-0313, Revision 1 require that such areas with the potential of forming a crevice condition should be inspected 100% during each outage. Based on several discussions with the licensee regarding our concern in this matter, the licensee agreed by letter dated September 6, 1984 to inspect the thermal sleeve attachment weld areas of five recirculation inlet nozzle safe-ends (two safe-ends per heat of material) in Browns Ferry Unit 2 during its current refueling outage. Since Unit 2 is similar in design to Unit 3 (material, vendor, vintage) and has more operating hours, it is a conservative representation of the two units.

If cracks are detected in the attachment weld areas of the safe-ends of Browns Ferry Unit 2, the licensee proposed in the September 6, 1984 letter to perform a similar inspection on Browns Ferry Unit 3 in accordance with the following schemes:

1. If cracking on unit 2 is minor (i.e., two or more reportable indications not requiring repair), unit 3 will be inspected for similar indications within 180 days.

2. If more serious cracking is noted on unit 2 (i.e., one or more indications of cracking requiring repair), unit 3 will be inspected for a similar condition within 60 days.

3. If unit 2 or 3 should develop leakage due to cracking in the subject area, the companion unit will be shut down within 14 days to inspect for a similar condition.

We reviewed the currently amended (Amendment No. 60) Technical Specification of Browns Ferry Unit 3 and noted that the leakage limit of 2 gpm increase in a 24 hour period has already been incorporated. We also noted that the currently amended Technical Specification requires leakage monitoring once every eight hours and allows 72 hours to fix the inoperable leakage monitoring system, which are not consistent with Generic Letter No. 84-11. In addition to the leakage limit of 2 gpm increase in a 24 hour period. Generic Letter No. 84-11 calls for leakage monitoring every four hours, fixing an inoperable leakage monitoring system within 24 hours and performing visual examination when the containment is deinerted. Therefore, we recommend that the licensee upgrade the leakage monitoring requirements to the level consistent with that delineated in Attachment 1 of Generic Letter No. 84-11.

5.0 CONCLUSION

We conclude that the Browns Ferry Unit 3 jet pump instrumentation penetration nozzle assemblies have been inspected and repaired in accordance with all current staff guidelines, and the plant can be safely returned to operation in its present configuration until the next refueling outage.

To further ensure nozzles and piping integrity, we recommend that the licensee upgrade the leakage monitoring requirements to a level consistent with that delineated in Attachment 1 of the Generic Letter No. 84-11.

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Dated: October 12, 1984