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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

COMMONWEALTH EDISON COMPANY
AND
IOWA-ILLINOIS GAS AND ELECTRIC COMPANY
QUAD CITIES STATION, UNIT 1
DOCKET NO. 50-254

REINSPECTION AND REPAIRS OF QUAD CITIES UNIT 1 REACTOR COOLANT SYSTEM PIPING

During the current Quad Cities Unit 1 1984 refueling outage, a total of 128 stainless steel piping welds were ultrasonically inspected in accordance with Generic Letter 84-11. Of these, 92 welds were in the recirculation system, 19 welds were in the residual heat removal (RHR) system, seven (7) welds were in the core spray system, four (4) welds in the reactor water cleanup (RWCU) system, and three (3) welds in each of the head vent and control rod drive (CRD) return systems. In the recirculation system, except for 19 welds, all welds were inspected. Of the 19 uninspected welds, nine (9) were nozzle to safe end welds which were not inspected due to high radiation exposure, six (6) were solution annealed sweepolet to header welds and four (4) were 4" by-pass stubs welds. In the RHR and core spray piping systems, the percentage of welds inspected in each pipe size varied from 21% to 35%. In the RWCU, CRD return and head vent systems, all accessible welds were inspected. In addition, because of recently reported cracking of jet pump instrument nozzle assembly welds, all 10 welds in such nozzle assemblies were inspected.

Lambert, McGill and Thomas (LMT) performed the ultrasonic testing (UT) for the licensee (Commonwealth Edison Company, (CECO)). Supplemental UT examinations on selected areas were performed by Universal Testing

Laboratories/Kraftwerke Union (UTL/KWU) to confirm the welds called by LMT to be circumferentially cracked. All inspection results were reviewed and evaluated by CECO UT personnel and the most conservative results were reported to NRC.

The UT inspection techniques used by each inspection team in this outage were the same as previously used at Dresden Unit 3 and Quad Cities Unit 2. The licensee indicated that all their UT personnel performing evaluations were qualified at NDE center and those performing scanning were qualified on-site on Nine-Mile-Point field samples. Region III of the NRC has determined that their UT procedures, calibration standards, equipment and IGSCC detection capabilities were satisfactorily demonstrated in accordance with I&E Bulletin 83-2, and that the same procedures and techniques were used in the UT examinations. Region III also indicated that all their UT personnel conducting these inspections have received appropriate training in IGSCC inspection using service induced IGSCC cracked thick-wall pipe specimens.

The results of UT inspections indicated that a total of 18 recirculation welds showed reportable linear indications. Of these, 14 are 12" riser welds, two (2) are 22" header welds and two (2) are 28" welds. 19 welds inspected in this outage were inspected during the 1982 outage. None of these welds showed linear indications. Except for one (1) 28" weld, axial indications with length varying from ¼ to 1.5 inches were found in 17 flawed welds. Circumferential indications were reported in nine (9) welds. The length of the circumferential indications were generally short. Only one (1) riser weld was reported to have a length exceeding one third of the circumference. The deepest circumferential indication with a depth of 65% wall thickness was reported in a riser weld (02E-S4). All axial indications were assumed through wall and were not sized for depth. Therefore, welds showing axial indications were all overlay repaired. The licensee indicated that leakage through axial flaws was observed in a total of nine (9) welds (12" riser) during weld preparation for Induction-Heating-Stress-Improvement (IHSI) or overlay application. Each leak was excavated and plugged prior to the completion of weld overlay repair.

Except for welds 02BS-S12 and 02BS-S9, 16 (14 12" riser welds and two (2) 22" header welds) of the 18 welds showing linear indications were weld overlay repaired. The two (2) axial flaws (0.8" maximim length) in weld 02BS-S12 (28") were removed by core drilling and were repaired by welding two (2) 1 5/16 inch diameter plugged half-couplings. Based on fracture mechanics analyses, weld 02BS-S9 (28") containing two (2) small circumferentical flaws (18% in depth and 3 inches in total length) was not repaired.

The licensee indicated that 77 welds in the recirculation system and 11 welds in the RHR system were treated with IHSI during this outage.

Ultrasonic examinations were performed on each weld after application of IHSI. Two (2) flawed 28" welds not overlay repaired were treated with IHSI to prohibit further crack growth. Region III of the NRC indicated that IHSI was satisfactorily performed in accordance with the qualified procedures.

NUTECH performed flaw evaluations for the licensee. The results of the evaluation indicated that weld 02BS-S9, a 28" pipe to elbow weld did not require weld overlay repair. Weld 02BS-S9 was reported to contain three (3) indications, namely, one inclusion and two circumferential flaw indications. The inclusion, with a radial extent of 0.05 inch (4% of wall thickness) and a length of 4 inches was located at a distance of 0.12 inch away from the pipe inside surface. Based on ASME Section XI - Table IWB-3514-2 (1983), the allowable flaw depth is 10.4%; therefore, the inclusion is acceptable without repair. NUTECH's IGSCC crack growth calculations also indicated that the circumferential flaws in weld 02BS-S9 can be left as-is without further repair because the crack growth at the end of the next fuel cycle is well within the 2/3 of ASME Code, Section XI, IWB 3640 limits.

NUTECH designed the weld overlay. 16 defective recirculation welds (14 12" riser welds and two (2) 22" header welds) were weld overlay repaired. The overlay thickness was designed to meet the ASME Code

Section XI IWB-3640 limits. For seven (7) defective welds with only axial flaws, a thin layer with a minimum thickness of 0.125 inch was designed to provide a leakage barrier. A thin overlay was also designed for weld 02B-S10 (22") because the circumferential flaw in the subject weld was short (3 inches) and shallow (10%). For the other eight (8) defective riser welds, an overlay with a minimum thickness of 0.195 inch was designed to provide additional structural reinforcement. NUTECH's overlay design conservatively assumed the circumferential flaws to be through wall cracks; however, the design took the thickness of the first overlay layer into credit. In overlay fabrication, penetrant test (PT) was not performed after the first layer. In lieu of PT, the follwing were performed:

1. Measurement of delta ferrite content,
2. enhanced visual examination for cracks, lack of fusion and other evidence of flaws,
3. reviewing of video taped first layer welding for evidence of flaws.

NUTECH considered that this program is at least as effective as PT in assuring that the first layer is an effective crack barrier. As will be discussed later, this alternative program for PT and the designed overlay thickness are considered acceptable. The licensee indicated that the maximum shrinkage stress as a result of weld overlay in the recirculation system is 15 ksi, which is well within the ASME Code limit.

To ensure a timely investigation of unidentified leakage, the licensee indicated that each item in attachment 1 to Generic Letter 84-11 for leak detection and leakage limits will be imposed on Quad Cities Unit 1.

Evaluation

We have reviewed the licensee's submittals, including the ultrasonic examination results, weld overlay design and the flaw evaluation to support the continuing service of an 18-month fuel cycle of the 16 overlay repaired recirculation welds (14 12" riser welds and two (2) 22" header welds), one (1) IHSI treated defective weld (28" recirculation weld 02BS-S12) repaired by installation of two (2) half-coupling and one (1) IHSI treated unrepared defective weld (28" recirculation weld 02BS-S9).

Weld 02BS-S12 was reported to have two (2) short axial flaws (0.8 inch maximum). The axial flaws were removed by drilling out two (2) 1½ inches diameter through wall plugs. The holes were sealed by installing two (2) half-coupling. The lost piping materials due to removing the axial flaws are small (less than 3.5% of the affected cross-sectional area), which will not have any significant effect on the structural strength of the piping. The unrepaired weld 02BS-S9 was reported to have two (2) small circumferental flaws with a maximium depth of 18% of wall thickness and a total length of about 3 inches. The sustained load on this weid including the shrinkage stress (1 ksi) is reported to be 8.2 ksi. We performed an independent crack growth calculation by using a conservative crack growth curve representing the upper bound of the weld sensitized materials. The stress intensity factor (K) was calculated by using an influence function and by conservatively assuming a full 360 degree crack with a depth of 18% of wall thickness. The result of our calculation indicated that the crack growth at the end of an 18-month period will not exceed 39% of the wall thickness. We also performed a calculation for the growth of crack length. We assumed the growth in crack length to be proportional to the growth in crack depth. The crack length at the end of an 18-month period is calculated to be about 11% of the circumference. In addition, we performed an independent limit load analysis to evaluate the design safety margin that will be present in the unrepaired weld 02BS-S9 based on the above calculated flaw size at the end of an 18-month period. A flow stress of 41.1 ksi and an axial stress of 6.44 ksi were used in the analysis. The flow stress corresponds to half of the ASME Code allowed yield stress plus tensile stress for 304 stainless steel at a temperature of 550°F and the axial stress corresponds to a design pressure of 1150 psi. The limit load calculation has shown that there is a safety margin over a factor of 16 on the bending stress (2.7 ksi), which includes the primary (dead weight and seismic stress) as well as the secondary (thermal stress and shrinkage stress) bending stresses. Therefore, we agree with the licensee's conclusion that the continued operation for an 18-month period with the defective weld 02BS-S9 in its as-is configuration is justified because the code design safety margin would be maintained. Furthermore, the unrepaired defective weld was mitigated with IHSI. The compressive residual stresses introduced as a result of IHSI process will prohibit the crack growth in depth and in length.

We have reviewed NUTECH's overlay designs for the 16 defective welds. Except for welds 02J-S4 and 02K-S3, the reported flaws in the repaired welds were short (< 10% of circumference). The circumferential flaws in welds 02J-S4 and 02K-S3 were reported to have a length of 35% and 28% of the circumference, respectively. We had concerns regarding the conservatism of the NUTECH's overlay design thickness of 0.195 inch for these two (2) welds. Therefore, we performed an independent limit load analysis to calculate the attendant safety margin in overlay repaired welds 02J-S4 and 02K-S3. The calculation procedure is the same as that described above for weld 02BS-S9. The minimum overlay thickness of 0.195

inch was used in the calculation and the circumferential flaws were conservatively assumed to be through wall cracks. The results of our limit load calculation have shown that the design safety margins on the bending stress of the overlay repaired welds 02J-S4 and 02K-S3 are 4.8 and 4.1, respectively, which substantially exceed the Code required safety margin. If the as-build overlay thickness was used, the safety margins in welds 02J-S4 and 02K-S3 were about 5.4 and 4.5, respectively.

NUTECH's overlay design takes the thickness of the first layer of overlay into credit and during overlay fabrication, the requirement of PT on the first layer is replaced by a program of delta ferrite examination of the first layer plus an enhanced visual examination during welding as well as a review of the video taped welding of the first layer for flaws and other imperfections. The purpose of requiring PT of the first layer and not allowing the credit of the thickness of the first layer is to provide additional conservatism in overlay design. These additional design margins were considered desirable because at the time the subject requirements were introduced, there were substantial uncertainties in the UT crack depth sizing, and experimental measurements had not been performed to support the presence of beneficial residual stresses resulting from weld overlay repair. Since then, the quality of UT crack depth sizing has been greatly improved and the extent of the beneficial compressive residual stresses from weld overlay repair have been substantiated by both analytical and experimental measurements. Therefore, we consider that the original additional design conservatism for overlay is not needed if the IGSCC resistance and the integrity of the first layer were demonstrated. We conclude that the licensee's program to demonstrate the IGSCC resistance and the integrity of the first layer is adequate, and therefore, the NUTECH overlay design thickness, which includes the first layer, is acceptable.

We have reviewed the licensee's reinspection program of piping welds susceptible to IGSCC in Quad Cities Unit 1 during the current 1984 refueling outage. A total of 128 welds were inspected in six (6) piping systems. In addition, all 10 welds in the jet pump instrument nozzle assembly welds were inspected. In the recirculation system all IGSCC susceptible welds in the 12", 22" and 28" pipes as well as 50% of 4" by-pass stubs welds and 25% of the nozzle to safe-end welds were inspected. 100% of accessible welds were also inspected in the RWCU, CRD return and head vent systems. In the core spray and RHR systems, at least 20% of welds in each pipe size were inspected. We conclude that the licensee's reinspection program met the guidelines in Generic Letter 84-11.

Conclusion

We have reviewed the licensee's submittals. We conclude that the Quad Cities Unit 1 plant can be safely returned to power and operated in its present configuration for one 18-month fuel cycle.

Nevertheless, there remains a residual concern regarding the long term growth of small IGSCC cracks that may be present but not detected during this inspection. Therefore, we require that plans for inspection and/or modification of the recirculation and other reactor coolant pressure boundary piping systems during the next refueling outage be submitted for our review at least three (3) months before the start of the next refueling outage.

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Date: August 2, 1984