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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSPECTION AND REPAIR OF REACTOR COOLANT SYSTEM PIPING

POWER AUTHORITY OF THE STATE OF NEW YORK

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

DOCKET NO. 50-333

1.0 INTRODUCTION

During the current FitzPatrick 1985 refueling outage, a total of 38 stainless steel piping welds were ultrasonically inspected in accordance with Generic Letter 84-11. Of these, 24 welds were in the recirculation system, six welds were in the residual heat removal (RHR) system, two welds were in the reactor water cleanup (RWCU) system and six welds were in the core spray (CS) system. The 38 welds inspected during this outage included six unrepaired defective welds, 20 welds not previously inspected, and 12 previously inspected welds.

Qualified personnel from EBASCO Services, and Kraftwerk Union (KWU) performed the ultrasonic testing (UT) for the licensee (Power Authority of the State of New York, PASNY). All inspection results are as reported after Induction Heating Stress Improvement (IHSI). The UT inspection showed crack-like indications in end-cap weld #22-22 and in four of the six unrepaired welds found cracked during the October 1984 outage. The end-cap weld #22-22 was first inspected in 1983 by EBASCO and was reported to have a small circumferential crack with a length of 1.9 inches and a maximum depth of 20.3% of the pipe wall thickness. In March 1984, the same end-cap weld was reinspected by KWU and the UT results indicated that this weld was not cracked; the indications were determined to be geometric in nature. During this current outage, extensive UT reinpsection was performed on this weld by EBASCO and KWU. By using various improved examination techniques, both EBASCO and KWU confirmed the presence of crack-like indications. The crack-like indications were reported to have a total circumferential length of 51.6 inches and a maximum throughwall depth of 27%. This defective end-cap weld was overlay repaired in this outage.

The results of the UT reinspection of the six unrepaired defective welds are summarized in Table 1. These indicate that three welds (#12-4, #12-17 and #28-53) did not show any crack growth and two welds (#28-48 and #28-113) were not cracked because the indications were determined to be from either weld root or weld counter bore. The cracks in weld #28-112 appeared to have substantial growth in length. The licensee indicated that the apparent length growth was solely attributed to the increased sensitivity of new techniques used in sizing. In the current inspection, the recording levels of crack length end points were either 10% of the highest indication amplitude or to the noise level, whichever was lowest.

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However, in the October 1984 inspection, the recording levels of the end points were at 50% reduction of the maximum amplitude. As shown in Table 1, the crack length in weld #28-112 was increased from 0.6 inch to 4.72 inches. To demonstrate that the apparent growth in crack length in weld #28-112 was a result of using more sensitive sizing techniques, weld #28-112 was reexamined by using the October 1984 sizing techniques, and a crack length of 0.6 inch was obtained. This crack length reexamination was witnessed by the NRC Region I inspector. The licensee indicated that for the purpose of evaluation and reinspection, all six unrepaired welds were considered cracked and the most conservative crack sizes reported were used in the crack growth analysis.

During the October 1984 outage, Structure Integrity Associates (SIA) performed two crack growth calculations for the licensee on each of the six unrepaired welds. One calculation was based on the standard distribution of as-welded residual stresses and the other calculation was based on the distribution of post-IHSI residual stresses as published in EPRI Report NP-2662-LD dated December 1982. Because of the reported crack length increase in weld #28-112 during this outage, SIA recalculated the crack growth in weld #28-112 based on the increased crack length. The results of the recalculation were similar to the previous calculation. For the other five unrepaired welds, the results of the previous calculations would continue to hold because there was no reported crack growth. In summary, SIA's crack growth calculation indicated that, when the favorable post-IHSI residual stresses were considered, there was practically no crack growth in each of the six unrepaired welds. Even if the as-welded residual stresses were considered, the final crack sizes in the four 28" welds at the end of a 36-month period would not exceed the Code-allowable flaw sizes in IWB-3600. However, in welds #12-4 and #12-17, the Code-allowable flaw sizes would be exceeded after a period of 9 months and 5.5 months, respectively, without the IHSI treatment. Based on SIA's crack growth evaluation, the licensee concluded that the continued operation of the FitzPatrick plant for an 18-month fuel cycle, considering the observed crack indications in the six unrepaired welds and the applied IHSI treatment, will not lead to a reduction in plant safety margin or a plant operational problem.

SIA also performed the weld overlay design for the licensee on the cracked end-cap to manifold weld #22-22. The cracks in the end-cap weld have a total length about 76% of the pipe circumference. The weld overlay design conservatively assumed the observed cracks to be completely through the original pipe wall and still met the ASME Code IWB-3600 allowable limits. The minimum length was designed to be about 5 inches, approximately equal to 1.5 $(RT)^{\frac{1}{2}}$, where R is the pipe outside radius T is the pipe wall thickness. The licensee indicated that the overlay was made of Type 308L stainless steel with a maximum carbon level of 0.02% and was deposited by automatic tungsten inert gas (TIG) welding technique, using a controlled low heat input (less than 40 KJ/in) process with water in the pipe to minimize the sensitization of the adjacent piping materials and to ensure a favorable residual stress pattern. A liquid penetrant test (PT) was performed on the first layer of the overlay and ferrite levels were measured at each layer with a target minimum of 8 FN. Credit for the first layer was not taken in the overlay design. After the completion of the overlay fabrication, UT examination was performed to ensure the bond integrity and the soundness of the overlay weld metals.

2.0 EVALUATION

We have reviewed the licensee's submittals dated April 26, May 3, and May 9, 1985, including SIA's fracture mechanics evaluation and weld overlay design, to support the continuous operation of the FitzPatrick plant for a 18-month fuel cycle in its present configuration.

UT Inspection

We have reviewed the information provided by the licensee regarding the UT inspection results from the 1985 inspection and taken into consideration the differences in the examination results from the October 1984 inspection as illustrated in Table 1. We concluded that the current 1985 inspection is acceptable because the inspection is more thorough and uses more sensitive techniques and upgraded instruments. We also conclude that there has been no significant crack growth in the six unrepaired defective welds considering the effect of various inspection techniques and the uncertainties associated with the UT inspections. The licensee has satisfactorily demonstrated that the apparent crack growth in weld #28-112 is a result of using a lower recording level criteria for crack end points in this outage.

For a more accurate measure of the crack length, we recommend that the criteria for the recording of crack end points used in this outage should be used in future inspections. The inspection results from this outage also indicated that welds #24-48 and #28-113 were not cracked. In view of the widely recognized technical problem, especially for the large-diameter piping, in the ability of differentiating between ultrasonic responses from IGSCC and innocuous reflectors adjacent to the weld root along the fusion line or the weld counter bore, we recommend that additional confirmatory tests other than conventional UT, such as the metallographic examination of plugs taken from the subject welds, should be considered to further demonstrate that these welds are truly not cracked. In the meantime, these two welds will be considered to be cracked.

Crack Growth Evaluation

We have reviewed SIA's crack growth calculations for the six unrepaired welds in the as-welded condition as well as in the post-IHSI condition. We conclude that the continued operation of the FitzPatrick plant for an 18-month fuel cycle with the six unrepaired defective welds in the present configuration is justifiable because the Code-required design safety margin of the piping can be maintained and the integrity of the reactor coolant pressure boundary will not be compromised. Our conclusion is primarily based on the following considerations:

(1) The results of the UT reinspection performed on the six unrepaired welds during this outage has shown that, after an operating period of about 3 months, there is practically no crack growth in those welds. This limited field experience provides some assurance that excessive crack growth in the six unrepaired welds is not likely to occur during the next fuel cycle.

(2) The six unrepaired welds were all treated with IHSI. IHSI treatment will redistribute the residual stresses in the pipes such that the compressive residual stresses will be at the inner portion of the pipe. This favorable residual stress distribution has the benefit of preventing crack initiation and propagation from the inside surface of the pipes. Due to the lack of adequate field experience and laboratory test data on cracked pipes treated with IHSI, we consider it premature to accept full theoretical IHSI benefit on cracked pipes for preventing crack growth as used in SIA's crack growth calculations. Furthermore, to realize the full IHSI residual stress benefit, the effectiveness of the IHSI treatment as well as the accuracy in crack depth measurements must be reasonably assured because, in the case of a deep crack, accelerated growth in depth will occur when the crack encompasses the region of tensile residual stresses. Therefore, in the interim, we will only recognize IHSI benefit on piping with short (less than 10% of pipe circumference) and shallow (less than 30% of wall thickness) cracks. The IHSI benefit also relies on the absence of a loading condition that will relax the favorable compressive residual stresses during plant operation. The largest sustained load including the secondary thermal stresses in the six unrepaired welds as reported by the licensee is about 17 ksi. This is substantially less than the yield stress of the piping material and, therefore, is not expected to cause significant relaxation of the favorable residual stresses.

Because of the potential uncertainties in the UT crack depth measurements, we conservatively performed a limit load analysis to determine the maximum allowable crack length for a throughwall crack in weld #12-4. Weld #12-4 has the largest stress ratio (1.06) in the six unrepaired welds and, therefore, bounds the calculations of all other welds. To provide adequate safety margins for the potential low toughness in the piping welds, we included secondary thermal stresses in the calculations and also applied a factor of three on both the axial and bending stresses. The result of our calculations indicated that a throughwall crack with a length of 10% of the pipe circumference in weld #12-4 will not exceed one-third of the limit load. Based on our limit load analysis and the reported short crack length (less than 5% of the pipe circumference) in the six unrepaired welds, we conclude that rupture of the unrepaired piping welds is not likely to occur even if the cracks were grown throughwall at the observed length. Furthermore, the leakage from the throughwall cracks can be detected by the reactor coolant leakage monitoring systems in the plant.

(3) The cracks in the six unrepaired welds, based on the most conservative UT indications, are relatively short (less than 5% of pipe circumference) and shallow (less than 17% of the pipe wall thickness). In addition, the results of the current inspection indicated that two of the six unrepaired welds are not cracked and the indications in the other two welds are below the recording level.

(4) The detection and sizing of IGSCC in this outage were performed by experienced UT personnel qualified at the EPRI NDE Center, Charlotte, North Carolina, using upgraded instruments and advanced techniques. It is not likely that any deep cracks in the unrepaired welds will be missed during the current inspection.

Weld Overlay Repair

SIA's overlay design for the end-cap weld #22-22 was based on the conservative assumption that all cracks were throughwall cracks. This assumption eliminates the uncertainties in the UT sizing of crack depth because crack depth need not be considered in the overlay design. The overlay of weld #22-22 was designed to the assumption of the entire pipe cracked throughwall because the total crack length exceeded 50% of the pipe circumference. The "as-built" effective overlay thickness was reported to be about 0.44 inch, which is thicker than the designed minimum thickness of 0.323 inch. The ferrite level measured on each overlay layer was reported to vary from 10 to 17.5 FN, which exceeded the required minimum of 8 FN. The licensee reported that the measured axial shrinkages due to overlay repair varied from 0.076 inch to 0.159 inch. Because the repaired end-cap weld is free at one end, the reported axial shrinkages can be accommodated by the end cap without developing any significant stresses in the recirculation system.

Augmented Reactor Coolant Leakage Detection and Monitoring

Although the conservative calculations discussed above indicated that the cracks in the unreinforced welds will not progress to the point of leakage during the next 18-month period, and very wide margins are expected to be maintained over crack growth to the extent of compromising safety, uncertainties in crack sizing and growth rate still remain. Because of these uncertainties, it is prudent to tighten the requirements for monitoring of unidentified leakage. The licensee has agreed to implement the additional monitoring and tighter limits on unidentified leakage in accordance with those delineated in Attachment 1 to Generic Letter 84-11.

Scope of Inspection

We have reviewed the scope of inspection performed in this outage. Based on the inspection performed in the three successive outages (Spring 1983, October 1984 and March 1985) subsequent to the I&E Bulletin 83-02 inspection, we conclude that the licensee has satisfactorily completed the piping inspection and repairs in accordance with the guidelines in Generic

Letter 84-11. The licensee did not reinspect the five overlay repaired welds in this outage because those welds were repaired only about 3 months ago during the October 1984 outage. We consider this to be acceptable.

3.0 CONCLUSION

We have reviewed the licensee's submittals and performed an independent evaluation. We conclude that the FitzPatrick plant can be safely returned to operation in its configuration for the duration of Cycle 7.

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TABLE 1

SUMMARY OF REINSPECTION OF UNREPAIRED CRACKED WELDS

DURING 1985 OUTAGE

Welds (#)	Loop	Weld Location	1985 Inspection Length	1985 Inspection Depth	1984 Inspection Length	1984 Inspection Depth
12-4	A	Pipe to Sweepolet	1.1"	7%	1.18"	7.5%
12-17	A	Pipe to Safe-end	1.4"	10%	2.9"	10%
28-48	A	Pipe to Safe-end	Not cracked		1.1"	15%
28-53	A	Elbow to Value	0.4"	5%	0.4"	5%
28-112	B	Elbow to Valve	4.72"	16%	0.6"	17%
28-113	B	Valve to Pipe	Not cracked		0.5"	10%