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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

POWER AUTHORITY OF THE STATE OF NEW YORK

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

DOCKET NO. 50-333

INSPECTION AND REPAIRS OF THE RECIRCULATION SYSTEM PIPING

Introduction

The Fitzpatrick plant was shut down on September 15, 1984 to perform mitigation measures on the recirculation system piping welds with induction-heating-stress-improvement (IHSI). During this scheduled outage, a total of 84 recirculation piping welds were treated with IHSI and each weld was ultrasonically tested (UT) after IHSI. Qualified personnel from EBASCO services, Incorporated, New York Power Authority (NYPA) and Universal Testing Laboratories (UTL)/Kraftwerk Union (KWU) perfomed the UT for the licensee (NYPA). The results of the ultrasonic examinations determined that seven 12" riser welds and four 28" welds contained intergranular stress corrosion cracks (IGSCC). This includes one unrepaired 28" weld, which was found cracked during the March 1984 outage. Five of the 11 cracked welds were previously inspected under I&E Bulletin 83-02 during the June 1983 outage and no cracks were found in these welds. The details of the ultrasonic examinations, including a comparison of the UT techniques used between this outage and the 1983 outage, will be discussed in a later section.

Region I of the NRC has reviewed the UT procedures, personnel qualification records, ultrasonic examination data, observed examinations in progress (detection and sizing), and has observed a completed overlay repair and ultrasonic measurement of the overlay thickness. The region verified that the examinations were done using procedures which were qualified in accordance with IE Bulletin 83-02 and that the sizing of cracks was done using the latest recognized techniques and equipment.

The Region further verified that examination and crack sizing personnel were qualified and had demonstrated their ability to perform those activities at the EPRI NDE Center at Charlotte, North Carolina.

The licensee reported that pin hole leaks were observed in three 12" riser welds (one leaker in weld #12-12 and two leakers in welds #12-64 and #12-69). Except for the leakers where the orientations could not be determined, all the observed cracking was oriented in the circumferential direction. The cracking in the seven 12" riser welds was more severe than that in the four cracked 28" welds. Four 12" riser welds (welds #12-12, #12-69, #12-23 and 12-64) were reported to have crack like indications intermittently around the entire circumference. The maximum circumferential crack depth of 75% of the wall thickness was reported in a 12" riser weld #12-23. The cracks in the four 28" welds were relatively short (< 3% of circumference) and shallow (< 17% of wall thickness). The majority of the cracked 12" welds were pipe to safe-end welds. The licensee indicated that the pipe to safe-end welds were generally the last installed field weld in each riser pipe line. These safe-end to pipe welds may have significant fit-up stresses and consequently, are more susceptible to IGSCC. Five of the 11 cracked welds (12" riser welds) were reinforced by weld overlay repair and the remaining six cracked welds, as justified by crack growth calculations, were not repaired.

Except for two 28" welds, the licensee has applied IHSI and performed ultrasonic examination on every weld in the recirculation piping system (97 welds). This includes the 11 welds mitigated by IHSI during the March 1984 outage. The two 28" welds were not accessible for UT and IHSI because of their location under pipe whip restraints.

Structural Integrity Associates (SIA) performed two crack growth calculations for the licensee on each of the five unrepaired welds (two 12" welds and three 28" welds) found cracked during this outage.

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 the EPRI report NP-2662-LD dated December, 1982. Where the favorable post-IHSI residual stresses were considered in the calculations, there is practically no crack growth in each of the five unrepaired welds.

In the as-welded case, crack growth in weld #12-17 (12") is most limiting. SIA's crack growth calculation of weld #12-17 showed that the two-thirds of the Code IWB-3640 limit is exceeded in approximately 5.5 months. For the four 28" welds, more than 36 months are required before the Code allowable flaw sizes are exceeded. For the defective safe-end weld (#28-02-2-48) discovered during the March 1984 outage, fracture mechanics evaluation was also performed by SIA. The results of the SIA evaluation performed indicated that the final flaw size in weld #28-02-2-48 at the end of the plant life, not considering the beneficial on residual stresses due to IHSI, will not exceed the size allowable by Section XI, Paragraph IWB-3640, because the cracks arrested at about 40% to 50% of the wall thickness. Based on the SIA crack growth calculations, the licensee concluded that the continued operation of the plant until the upcoming refueling outage (January 1985) with the six unrepaired welds, considering the observed crack indications and the applied IHSI treatment, will not lead to a reduction in plant safety margins or a plant operational problem.

SIA also performed the weld overlay design for the licensee on five riser welds that required overlay repair. Four of those welds were riser pipe to safe-end welds and had intermittent cracks around the full circumference. The cracks in a riser pipe to elbow weld had a total length about 12.5% of the circumference. The weld overlay designs conservatively assumed that the observed cracks were completely through the original pipe wall, over the entire observed length, and still met the ASME Code IWB-3640 allowable. The minimum length was designed to be about three inches, approximately equaled to $1.5(RT)^{1/2}$, where R is the pipe radius and T is the wall thickness. The licensee indicated that the overlays were made of low carbon (< 0.022% carbon) stainless steel weld metal and were deposited by automatic tungsten inert gas (TIG) welding technique using a controlled low heat input (< 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. Liquid penetrant tests (PT) and ferrite content tests were performed on the first layer of the overlay. Credit for the first layer of the overlay was not taken in the overlay design. UT examination was performed on the completed overlays to ensure the bond integrity and the soundness of the overlay weld metals.

The licensee indicated that prior to the upcoming outage (January 1985) a detailed plan regarding anticipated weld inspection activities in accordance with Generic Letter 84-11 will be provided for staff review.

Ultrasonic Examination

The staff's review of the UT methods used by the licensee during the current 1984 outage for the detection and sizing of IGSCC is based on the evaluation of the examination results from two (2) commercial inspection agencies and NYPA personnel employed by the licensee. Each of the commercial organizations used different instrumentation and a number of ultrasonic techniques to perform an integrated examination. The UT methods applied during both 1984 and 1983 outages will be described since different ultrasonic techniques were used and consequently, the examination results obtained for individual welds determined to contain IGSCC were different as summarized by the licensee in Table 1.

Inspection Techniques Used During 1984 for Detection and Sizing

The ultrasonic examination consisted of three phases: (1) UT detection, (2) UT discrimination and (3) UT flaw sizing. The detection examinations were performed manually primarily by Ebasco personnel using 45° and 60° shear wave transducers at 2 1/4 megahertz (MHz). Sizing was performed by UTL/KWU using various techniques including:

- Inside diameter (ID) mode conversion-creeping wave.
- SLIC 40-dual element multiple angle.
- 45°, 4 MHz.
- 60°, 4 MHZ.
- Dual element focused beam.
- Crack tip diffraction, 45°, 4 MHz.
- Head wave, creeping wave.

An ultrasonic examination for the purpose of detecting IGSCC was performed on all weldments subject to IHSI treatment. This examination consisted of performing a pre-IHSI examination on most weldments either during this outage or during previous 1983 and 1984 outages and also performing a post-IHSI UT examination on all weldments treated during this outage. The results of the examinations indicated that a total of 11 welds in Table 1 showed reportable crack indications.

Ebasco started the detection examination by establishing the profile of the weldment. The outside diameter (OD) was determined with a weld profile needle gauge. The ID profile was established through a combination of various sources of information; the main source being a 0° examination taken at various points around the weld. This examination was performed by scanning across the weld from the base metal across weld material to base metal while observing the instrument screen. Notations are made during this scan; i.e., counterbore and root locations, variances in thickness, and abnormalities. This information was then compared to the baseline radiographs and an accurate ID profile was assembled. Ebasco performed a manual 45° angle beam examination from both sides, when applicable, and when possible. All pipe-to-pipe, and pipe-to- elbow configurations were scanned on both sides. All pipe-to-pump, pipe-to-valve, and pipe-to-tee configurations were completed on the pipe side only. The heavy sections of the fitting and necessary weld taper preclude any examinations in these areas. No relevant ultrasonic information is available on the component side of the weld because ultrasonic examinations of the component side of the weld joint is not possible. However, the component side of the weld joint is usually fabricated from IGSCC resistant material such as cast stainless steel. The specific examination results were described on the Examination Summary Sheets attached to the licensee's submittal dated October 25, 1984. When a 45° angle beam examination was not possible due to excess weld crowns or ID weld contour, the weldment was examined by a 60° angle beam transducer. The 60° angle beam was also utilized by Ebasco to supplement the 45° examination when additional information was desired in discriminating UT signals. Ebasco provided results of all UT examinations to the NYPA Level III Examiner. Upon review of the Ebasco data and performance of any additional informational UT examinations, the NYPA Level III Examiner would direct the UTL/KWU examiners to perform additional discrimination and flaw sizing.

The flaw sizing of IGSCC was performed by KWU both manually and semi-automatically by examiners that passed the EPRI NDE Center Course, "UT Operator Training for Planar Flaw Sizing." The discrimination and flaw sizing consisted of the detection of areas which were identified by Ebasco (through the NYPA Level III) where signals were obtained which were suspected to originate from crack indications. Techniques used by KWU, WSY 70°

and 45° shear wave are sensitive to corner like reflectors. KWU would next determine the position at which the assumed crack is deepest by a rough crack depth estimation. KWU then measures the OD/ID profile using a contour gauge on the OD and using straight beam transducer to determine the weld centerlines and ID contour. Consideration for detectability and discrimination of cracks/geometry are done using the OD/ID profile.

Based on conclusions drawn above, further detection techniques (for example, 60° shear wave) were used where the inspection of geometry does not allow a complete coverage of the area required to be examined. To discriminate between cracks and geometry, KWU used additional techniques when necessary, such as 70° longitudinal probes to detect the possibility of cracks on the top of the counterbore. In the cases where the discrimination results indicate a crack, the crack depth was determined by detecting crack facet and the crack tip. All available techniques were used. Upon completion of discrimination and flaw sizing, all data is presented to the NYPA UT Level III for final review and acceptance. The final flaw sizing data was transmitted to Structural Integrity Associates (SIA) to proform a flaw evaluation.

Examination of Weld Overlays

An ultrasonic thickness measurement was performed on the pipe prior to any welding. A liquid penetrant examination was also conducted on the pipe prior to the 1st weld pass. After the 1st pass was completed, a PT and a visual (VT) examination was performed. If satisfactory, a ferrite check was made to ensure ferrite content between 10-20 FN and, another UT thickness was taken. Successive passes were then performed to bring the cladding up to the required overlay design thickness and width criteria with visual examinations and ferrite content checks performed after each pass. On the final pass a VT, PT, UT thickness check, and ferrite content examination was performed. If these tests were satisfactory, a lack-of-bond examination was performed using UT techniques. Finally, the weld overlay was pressure tested at 100% of the operating pressure of the recirculation system.

Inspection Techniques Used During 1983 for Detection and Sizing

The 1983 inspection was conducted by EBASCO personnel with essentially the same examination procedure and techniques as described above for EBASCO during 1984 inspection. However, EBASCO and NYPA personnel made the characterization of the origin of ultrasonic indications in 1983. A review of the licensee's summary of detected IGSCC in Table 1 shows a significant discrepancy in the inspection results for weld number 12-23. During the 1984 inspection a long (360° intermittent) and deep (75% through-wall maximum) IGSCC was identified in this weld that was determined to be not flawed in 1983. The General Electric Company also performed an inspection of weld number 12-23 in 1977. In the previous two inspections both EBASCO and General Electric identified ultrasonic indications that were deemed to be geometric in origin.

The licensee investigated the cause for the discrepancy between the examination results for weld number 12-23. During 1983 plotting of ultrasonic indications were based on a projected OD/ID profile (flat-topped weld crown and ideal ID profile) and did not reflect the actual field conditions. In addition to this, the examinations were performed using full-length 45° wedges which prevented the shoe from going beyond the "butt-up" position which is necessary to obtain a meaningful examination. The shortened (EPRI-modified) transducer wedges were not available until late (fall) 1983. Replotting of the 1983 data using 1984 ID/OD profile information shows that weld geometry was the cause of the indication recorded by EBASCO.

In the September 1984 outage, further investigation was performed by the NYPA and Ebasco Level III personnel including examination of OD profile. As a result it was determined that a 45° examination, even if performed with the EPRI-modified wedges, would not examine the area-of-interest (the heat affected zone between the counterbore and root) due to the O.D. configuration. Based on this information and the projected exit point versus area-of-interest relationship, a 60° examination was performed on weld 12-23. The remainder of the welds which have a similar OD profile, were also examined using a 60° shear wave if the 45° examination proved inadequate. As a result of these inspections, all pipe safe end welds which were inspected in 1983 were reinspected (i.e., welds 12-1, 12-7, and 12-75). These inspections, utilizing the 60° technique, revealed that these three weldments were free of reportable indications.

EVALUATION

We have reviewed the licensee's submittals including SIA's fracture mechanics evaluation and weld overlay designs to support the continuous operation of Fitzpatrick plant until the next refueling outage (January 1985) in its present configuration.

The staff has reviewed the information provided by the licensee regarding the examination results from the 1984 inspection and taken into consideration the difference in examination results from the 1983 inspections as illustrated by Table 1. During both refueling outages augmented inservice inspections for the detection of IGSCC were performed by inspection agencies qualified under I&E Bulletin 83-02 using different UT methods and instrumentation. In 1984 the licensee employed personnel that used a combination of techniques to demonstrate and qualify their flaw sizing capability. The staff has determined that the ultrasonic inspections performed by the licensee for detection and sizing of IGSCC during this outage were more thorough and, therefore, acceptable within the limitiations of the current state-of the-art and the design restrictions to examinations. This determination was based on the following considerations:

1. The qualified Ebasco inspection personnel used examination procedures and instrumention for detection during the 1983 and 1984 inspections are technically similar to most inspection agencies performing manual UT for the detection of IGSCC in BWR piping. The widely recognized technical problem is the ability to differentiate between ultrasonic responses from IGSCC and innocuous reflectors adjacent to the weld root and along the weld fusion line especially for the large diameter piping. The amount of supplement or reinspection is limited by ALARA constraints.

2. The examinations by KWU were performed with a combination of techniques at a high ultrasonic sensitivity with data that is recorded in a manner that would permit a more accurate location of the relative position of the weld fusion line and the reflector than during the 1983 inspection.

3. The staff considers the demonstrated and qualified abililty to size IGSCC before the current 1984 inspection as a benefit in the correct characterization of the condition of the weld.

4. All existing weld overlays of repaired welds were inspected by the licensee with manual UT procedures to verify the integrity of both the clad weld metal and its bond to the pipe base

material. The examination results obtained by the licensee did not identify any significant indications in the overlay or overlay-to-base metal interface. The staff concludes that the licensee has used experienced personnel to perform the examination of the clad weld metal and the examination performed by the licensee could detect lack of clad bond and could identify flaws in the clad weld metal that would affect the structural integrity of the clad overlay.

To ensure that excessive crack growth in the unrepaired defective welds will not occur during the remainder of the current fuel cycle (a period of approximately 3000 hours), the staff performed an independent crack growth calculation on weld 12-17. The crack growth in the unrepaired defective welds was bounded by this calculation because the riser weld 12-17 had the largest stress ratio (1.06) and the longest crack length (2.9 inches). The stress intensity factor (K_I) was calculated based on a cylindrical model of a 12-inch diameter pipe, assuming a complete 360° circumferential crack at a depth of 20% throughwall, which was double reported maximum crack depth in weld 12-17. The crack growth rate curve used in our calculation is slightly more conservative than that used by SIA, and is an upper bound of GE and EPRI crack growth data in furnace sensitized material tested in 0.2 ppm O_2 water.

The staff used the standard residual stress distribution corresponding to the large diameter piping in the calculations. Our calculations showed that the initial crack depth of 20% would grow to a depth of about 32% at the end of a period of 3000 hours as the crack is relatively short (about 8% of the circumference).

Because of the current concerns regarding the conservatism of the ASME Code Section XI IWB 3640 limits, the staff performed an independent limit load analysis to evaluate the safety margin that will be present in the above calculated final crack size, 32% of wall thickness at the end of a period of 3000 hours. The length of the final crack size was conservatively assumed to be 5.8 inches, about double original crack length. In our limit load analysis, we used a reduced flow stress of 41.1 ksi (corresponding to half of the ASME Code allowed yield stress plus tensile stress for type 304 stainless steel at a temperature of 550°F) and included the thermal expansion stresses in the safety margin calculation. Our limit load calculation has shown that there is a safety factor of about 4 on the bending stresses, which includes the primary (dead weight and seismic stresses) as well as the thermal expansion stresses. The calculated safety margin substantially exceeds the Code required safety margin of three.

SIA's overlay design for the five defective welds (12" riser welds) 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. Four of the five overlay designs did not take credit for the remaining uncracked piping ligament because the cracking in those four welds were assumed to be throughwall in the entire circumference. The overlay of weld #12-17 was designed to have throughwall crack about 40% of the circumference. The "as-built", effective overlay thickness on weld #12-70 was reported to be about 0.385" which is thicker than the designed minimum thickness of 0.23". The reported "as built" overlay thickness on weld #12-70 will meet the ASME Code IWB-3640 allowable without taking credit for the remaining uncracked piping section. The licensee reported that the measured axial shrinkages at the five overlay repaired welds varied from 0.135 inch to 0.223 inch and the maximum shrinkage stress was calculated to be 7000 psi at the sweepolet to riser pipe weld. The calculated maximum shrinkage stress is well within the code allowed secondary stresses. The shrinkage stresses on the unrepaired welds are small because the repaired welds were located on different pipe runs than the unrepaired welds.

Although the conservative calculations discussed above indicate that the cracks in the unreinforced welds will not progress to the point of leakage during the next 4 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 the Generic Letter 84-11.

The piping in the Fitzpatrick plant was not completely reinspected in accordance with Generic Letter 84-11 during the current outage. The licensee indicated that the reinspection to Generic Letter 84-11 will be completed during the upcoming refueling outage in January 1985. We consider that the licensee's schedule is acceptable, because it meets the intent of Generic Letter 84-11, which requires the reinspection to be performed within about two (2) years and the schedule may be adjusted to coincide with the next scheduled outage.

Conclusion

We have reviewed the licensee's submittals and performed the staff's own independent evaluation. We conclude that the Fitzpatrick plant can be safety returned to operation in its present configuration for a period of 3000 hours.

WELD SUMMARY

TABLE 1

JAMES A. FITZPATRICK - RESULTS OF IGSCC INSPECTIONS

Weld No.	Loop	Weld Location	Crack Type	Length	Thru Wall	Depth Var.	IHSI	Discovery Method	Previous Inspection	Corrective Action	Remarks
12-4	A	Pipe to sweep-o-let	C	1.0%	No	7.5%	Yes 9/84	UT-Pre & Post IHSI	6/83	IHSI & Analysis	
12-12	A	Pipe to safe end	C	100%	Yes 1	Avg.50% Max.100% Min.<5%	Yes 9/84	PT, Visual, UT, Post IHSI		Weld Overlay	See Note 1
12-17	A	Pipe to safe end	C	4.0% 3.0%	No	Max.10%	Yes 9/84	UT, Post IHSI	12/81	None	Indications 90% apart
12-23	A	Pipe to safe end	C	100% int.	No	Avg.40% Max.75% - Min.<5%	Yes 9/84	UT, Post IHSI	6/83	Weld Overlay	See Note 1
12-64	B	Pipe to safe end	C	100% int.	Yes 2	Avg.30% Max.100% Min.<5%	Yes 9/84	PT, Visual, UT, Post IHSI		Weld Overlay	See Note 1
12-69	B	Pipe to safe end	C	100%	Yes 2	Not aplt	Yes 9/84	PT, Visual UT, post IHSI	12/81	Weld Overlay	See Note 1
12-70	B	Elbow to pipe	C	12.6%	No	45%	Yes 9/84	UT, Pre-IHSI	12/81	Weld Overlay	
28-48	A	Pipe to safe end	C	1.1%	No	15%	Yes 3/84	UT, Pre-IHSI		IHSI & Analysis	
28-53	A	Elbow to valve	C	.3%	No	5%	Yes 9/84	UT, Pre-IHSI	6/83	IHSI & Analysis	
28-112	B	Elbow to valve	C	.6%	No	17%	Yes 9/84	UT, Pre-IHSI	6/83	IHSI & Analysis	
28-113	B	Valve to pipe	C	.5%	No	10%	Yes 9/84	UT, Pre-IHSI	6/83	IHSI & Analysis	

Note 1 - No pre-IHSI UT examination performed.