Attachment 1 to
RHB-84-032

QUAD CITIES UNIT 1

IGSCC FLAW DISPOSITION SUMMARY

June 27, 1984

Prepared by:

NUTECH Engineers, Inc.

for

Commonwealth Edison Company

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QUAD CITIES UNIT 1 IGSCC FLAW DISPOSITION SUMMARY

WELD	PIPE DIAMETER	IHSI	FLAW CHARACTERIZATION	FLAW DISPOSITION
02C-S4 P-EL	12"	YES	44% X 4" CIRC - PIPE 3 AXIALS 1" MAX - PIPE	OVERLAY 0.195' X 4.0"
02D-S4 P-EL	12"	NO	2 AXIALS 7/8" MAX - PIPE	OVERLAY 0.125" X 3.5"
02E-S4 P-EL	12"	YES	65% X 0.8" CIRC - PIPE 8 AXIALS 1.5" MAX - PIPE	OVERLAY 0.195" X 4.0"
02F-S4 P-EL	12"	NO	3 AXIALS 0.8" MAX - PIPE	OVERLAY 0.125" X 2.76"
02G-S3 EL-P	12"	YES	50% X 3/4" CIRC - PIPE 7 AXIALS 1 1/8" MAX - PIPE 1 AXIAL 7/8" MAX - ELBOW	OVERLAY 0.195" X 4.0"
02G-S4 P-EL	12"	NO	18% X 1" CIRC - PIPE 1 AXIAL 1/8" CON'TD - ELBOW	OVERLAY 0.195" X 4.0"
02H-S3 EL-P	12"	YES	21% X 3" CIRC - PIPE 3 AXIALS 3/4" MAX - PIPE	OVERLAY 0.195" X 4.0"
02H-S4 P-EL	12"	YES	4 AXIALS 3/4" MAX - BOTH	OVERLAY(1) 0.125" X C + 2.0"
02J-F6 SWP-P	12"	NO	4 AXIALS MIN 1¼" MAX - PIPE	OVERLAY(1) 0.125" X C + 2.5"
02J-S3 EL-P	12"	YES	12% X 0.6" CIRC - PIPE 1 AXIAL ½" CON'TD - PIPE	OVERLAY 0.195" X 4.0"
02J-S4 P-EL	12"	YES	6 CIRCS - 55% MAX X 13.25" TOTAL - PIPE 9 AXIALS 1.1" MAX - PIPE	OVERLAY 0.195" X 4.0"
02K-S3 EL-P	12"	YES	4 CIRCS - 25% MAX X 10.6" TOTAL - PIPE 5 AXIALS 5/8" MAX - PIPE	OVERLAY 0.195" X 4.0"
02K-S4 P-EL	12"	YES	2 AXIALS ¼" MAX - PIPE	OVERLAY 0.125" X 3.2"
02M-S3 EL-P	12"	YES	3 AXIALS 1" MAX - PIPE	OVERLAY 0.125" X 3.81"

QUAD CITIES UNIT 1 IGSCC FLAW DISPOSITION SUMMARY (Cont'd)

WELD	PIPE DIAMETER	IHSI	FLAW CHARACTERIZATION	FLAW DISPOSITION
02B-S10 P-CAP	22"	YES	10% X 2" CIRC - CAP 3 AXIALS 1/2" MAX - CAP	OVERLAY 0.125" X 3.55"
02B-S7 X-P	22"	YES	AXIAL FLAW IN HAZ-PIPE	OVERLAY(1) 0.125" X C + 0.75"
02BS-S9(2) P-EL	28"	YES	18% X 1 1/2" CIRC - PIPE 15% X 1/2" CIRC - PIPE	LEAVE AS-IS(3), IHSI ONLY
02BS-S12 EL-P	28"	YES	2 AXIALS 0.8" MAX - PIPE	FLAWS REMOVED VIA PLUG TWO SAMPLES(4)

NOTES:

1) C = Crown width, inches

2) UT inspection confirmed, in addition to the circumferential indications, the existence of a slag inclusion in Weld 02BS-S9 from original construction. Evaluation in accordance with IWB-3500 demonstrates its acceptability without further repair.

3) The circumferential indications were evaluated, using techniques previously accepted by the NRC Staff, and found to be acceptable without weld overlay.

4) Weld 02BS-S12 was repaired by welding on two 1 5/16 inch diameter plugged half-couplings.

Attachment 2 to
RHB-84-032

QUAD CITIES UNIT 1

IGSCC FLAW EVALUATION/DISPOSITION INFORMATION

June 27, 1984

Prepared by:

NUTECH Engineers, Inc.

for

Commonwealth Edison Company

ATTACHMENT C

QUAD CITIES UNIT 1

RESPONSE TO STAFF QUESTIONS

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This document provides Commonwealth Edison's responses to NRC Staff requests for information related to the IGSCC flaw evaluation and disposition during the Spring 1984 outage at Quad Cities Unit 1. The information is submitted in support of the Commonwealth Edison request for NRC concurrence to operate Quad Cities Unit 1 for the next fuel cycle.

Information is provided on the following topics:

- Weld 02BS-S9 Flaw Evaluation
- Weld Shrinkage - Induced Stress Evaluation
- Weld 02BS-S12 Repair Discussion
- One-Sided UT Examinations
- Weld Overlay Integrity Assurance
- UT Inspection Results - 1982 _vs_ 1984 Comparison
- Leaking Axial Through-Wall Flaw Summary

WELD 02BS-S9 FLAW EVALUATION

As a result of UT examination, three indications were identified in Weld 02BS-S9. Initial evaluation of the first flaw indicated that it was not due to IGSCC. Subsequent review of earlier UT results (1976) and the original construction radiographs confirmed that the flaw is a slag inclusion resulting from original construction. The flaw is located approximately 0.12 inches from the pipe inside diameter, with no connection to the inside surface. It has a radial extent of 0.05 inches and is 4 inches long.

The inclusion was evaluated using the methods of ASME Section XI, Subarticle IWB-3500. For the purposes of the evaluation, it was treated as a surface flaw. The pipe wall thickness is 1.25" at the flawed location. Using the above flaw data yields a flaw a/t ~ 4%. The allowable flaw a/t is 10.45% from Table IWB-3514-2 (1983). Therefore, the flaw is acceptable as-is without further evaluation. This evaluation will be formally documented in the Flaw Evaluation/Disposition Report to be prepared by NUTECH.

As a result of review of the LMT data tapes and reinspection by qualified LMT and Commonwealth Edison personnel, two additional circumferential flaw indications were identified: one is 18% x 1½" (pipe side) and the other is 15% x ½ inches (pipe side). These indications were also independently evaluated by UTL/KWU personnel. Their inspection indicated that there were no circumferential flaws, but instead a metallurgical discontinuity caused by backwelding. However, the Commonwealth Edison Corporate Level III Inspector conservatively dispositioned these results in accordance with the original LMT circumferential flaw evaluation. Consequently, both were evaluated using techniques previously accepted by the NRC Staff for Quad Cities Unit 2 and Dresden Unit 3. Based on this analytical evaluation these flaws can be left as-is, without further repair. Note, Weld 02BS-S9 was treated with Induction Heating Stress Improvement (IHSI) during the current outage. This analytical evaluation will also be included in the Flaw Evaluation/Disposition Report.

WELD SHRINKAGE-INDUCED STRESS EVALUATION

Axial shrinkage of weld overlay material during cooling may induce additional stresses at locations other than the overlaid location. Although such stresses are steady state secondary stresses, which are not limited by the ASME Code, high shrinkage stresses could increase the susceptibility to IGSCC initiation. Consequently, the effects of weld overlay shrinkage are evaluated.

The actual weld shrinkage of each overlay is measured in the field after application of the overlay. The measured values are used as input to a piping analysis of the affected system, and resulting stresses at all points in the system are determined. In the case of Quad Cities 1, only the recirculation system is affected since overlays were applied only to this system.

A comparison of measurements thus far at Quad Cities 1 with the evaluations performed for Quad Cities 2 and Dresden 3 indicates that the calculated stress levels will be acceptable. This conclusion will be formally documented in the Flaw Evaluation/ Disposition Report prepared by NUTECH. It should also be noted that all accessible unflawed welds in the Quad Cities 1 Recirculation System were treated with Induction Heating Stress Improvement (IHSI). This tends to mitigate the concern from weld shrinkage-induced stresses.

WELD 02BS-S12 REPAIR DISCUSSION

IGSCC flaws were identified at two locations in Weld 02BS-S12; the flaw locations were separated by 8 inches. Plug samples containing the flaws were removed for metallurgical analysis. The resulting holes were repaired using plugged half-couplings, which were attached using full penetration welds.

The combined material removed (two 1 5/16 inch plugs) represents a loss of less than 3 inches of circumference, out of a total circumference of 88 inches. The stresses at this location are low (stress ratio ~ 0.6). Therefore, Code margins on net section collapse are met.

Removal of the plugs may produce some local relaxation of the IHSI-induced residual stress pattern. However, this effect is not expected to be significant. The heat due to the welding of the couplings may also have some local effect on the IHSI residual stresses, but NUTECH studies have shown that this effect is confined to the immediate vicinity of the welding, and does not have a large magnitude through-wall effect for thick pipe (such as the 1.25 inch thick recirculation piping). Thus, it is concluded that the global residual stress improvement due to IHSI for Weld 02BS-S12 will be essentially unchanged by the removal and repair of plug samples.

ONE-SIDED UT EXAMINATIONS

The typical ultrasonic examination performed in accordance with the Commonwealth Edison procedure consists of many scans from several directions. Circumferential flaws are detected by scanning normal to the weld, axial flaws are detected with a slightly skewed scan parallel to the weld, and other types of flaws are detected with a transducer which directs the sound through the wall thickness. The first two of these are shear wave examinations conducted with an angled transducer (angle beam) and the last with a longitudinal transducer (straight beam). Each of these scans is performed from both sides of the weld to gain the best examination. However, certain configurations and metallurgical structures do not permit scanning from the base metal on one side of the weld. In these cases, the examination is performed from the other side and the restricted side is examined to the extent practical by directing sound through the weld.

Of the 138 ultrasonic examinations performed at Quad Cities Unit 1 on 4 inch and larger stainless steel piping during this outage, 26 welds were examined from only one side. A total of 17 of these were at welds to pumps and valves where the cast structure of the pump or valve does not allow a meaningful examination from that side. Since cast microstructures are immune from IGSCC, this does not cause any concern. The remaining 9 one-sided examinations were located at fitting welds, such as crosses and tees, where the fitting does not have sufficient extent to physically permit the transducer to be manipulated.

WELD OVERLAY INTEGRITY ASSURANCE

Attachment 2 (Crack Evaluation and Repair Criteria) of NRC Generic Letter 84-11 provides guidance regarding the minimum requirements for application of weld overlay repairs. Specifically,

- Paragraph 2.b.i requires that the overlay thickness be sufficient to provide full IWB-3600 margin given the crack propagates through-wall and also through the first weld overlay layer, unless crack arrest can be shown.

- Paragraph 2.b.i further states that the effective overlay thickness is that thickness deposited after the first layer which clears dye-penetrant testing (PT) examination. This is to demonstrate that the crack has been stopped.

- Paragraph 2.b.ii requires a minimum of two weld layers be deposited (after the PT clean layer) for short circumferential and axial cracks.

- Paragraphs 2.b.iii and 2.b.iv require that full structural overlays be applied for long flaws which approach a length that would cause limit load failure and require that short flaws are additive to determine the length used for such an analysis.

These minimum requirements were specified to establish the integrity of the weld overlay repair. The following paragraphs summarize the actions taken by Commonwealth Edison to assure the metallurgical ability of the weld metal to prevent IGSCC and to assure the general weld quality of the first layer deposited. These actions include those related to design conservatisms, repair techniques, weld material requirements, delta ferrite measurement of the first weld overlay layer, video taping, visual examination of the first weld overlay layer, and final examination of the weld overlay. Based on these actions it is considered that the requirements of Generic Letter 84-11 are met and exceeded.

Design Considerations

As stated at the NRC presentation on June 8, 1984, all the Quad Cities Unit 1 weld overlays have been shown to arrest the growth of the circumferential flaws. Additionally, the depth of all circumferential flaws in 12 inch pipe was assumed to be throughwall.

A minimum of two weld overlay layers is specified on the design drawing for all overlays of axial flaws. Three layers are applied for all overlays on welds with both axial and circumferential flaws.

No flaws at Quad Cities Unit 1 were of a length which approached limit load failure and as such, no full structural weld overlays were required.

Repair Techniques

All the overlays at Quad Cities 1 were applied to pipe welds which had been shown by UT to contain axial flaws. Thus, two techniques were used to seal-off any deep axial flaw from propagating into the first weld overlay layer. Note, all circumferential flaws were fairly shallow and short. As such they are not of concern in the weld overlay application process.

For deep axial flaws which are detected to be leaking during the surface preparation or after the IHSI process, the repair technique consisted of excavating approximately 3/16 inch depth of the crack from the OD and sealing the root of the excavation with a layer of 308L weld metal. The surface was then ground such that approximately 50% of the layer was removed. The resulting surface was PT examined to verify that the flaw was sealed. The remaining cavity was then filled with 308L weld deposit, surface finished and PT examined prior to the weld overlay operation.

For axial flaws which were detected to be leaking during the welding process, a cavity equal to the weld overlay thickness deposited plus 3/16 inch depth into the base metal was excavated. The full extent of the axial crack was excavated at the cavity depth to assure sealing. The cavity was then repaired using the method described above. Note, the compressive stress due to the deposited weld overlay layer tightens the flaw and aids in the repair. At least one layer of machine deposited GTAW is placed over the PT acceptable repair.

These repair techniques give assurance that all deep axial cracks detected are sealed with 3/16 inch of appropriate weld metal and are PT acceptable.

Welding Material Requirements

All welding material used for the weld overlays is required to meet the following pertinent requirements in addition to the other requirements of the material specification and ASME Section III, Subsection NB:

- All welding filler metal is low carbon (i.e., 308L). Carbon contents are typically 0.02%.

- All welding material has an as-deposited delta ferrite of > 8FN by actual measurement of as-deposited weld metal pad.

Delta Ferrite Measurement of First Weld Overlay Layer

After deposition of the first weld overlay layer the delta ferrite of the weld deposit is measured in the areas of the base metal. This is to avoid erroneously high readings over the original circumferential and longitudinal (seam) welds. The as-deposited reading must be > 7.5FN. If less than 7.5FN, the layer is not included in the weld overlay thickness. The conditions necessary to meet the delta ferrite requirement also assure that the first weld overlay layer has a low carbon content.

Welding Records

All welding, with the exception of the repairs previously discussed, is performed using remote GTAW with the capability to video tape the remote video output. The video tapes of the first layer are independently reviewed by the welding supervisor before the second weld layer is applied. Any anomaly not recorded on the welding log which may be evidence of a flaw ("blow-out", porosity, etc...) is mapped and repaired. The video display is magnified from 10 to 20 times assuring observation of minute defects.

Enhanced Visual Examination of First Weld Overlay Layer

Based on the successful application of over 200 weld overlays, NUTECH has observed the signs of flaws in the first weld layer (and subsequent layers). Discoloration of the weld bead, small porosity, and interbead lack of fusion are caused by the presence of small surface and subsurface flaws. The visual examination of the first weld overlay layer is performed by qualified visual examiners using the Commonwealth Edison visual examination (VT) procedure. The acceptance criteria of this procedure are supplemented for the first layer VT exam by the additional NUTECH acceptance criteria.

Final Examination

The final examination of the completed weld overlay consists of the following:

- Dimensional verification of thickness by UT, width and placement of the overlay using calibrated electronic calipers, and shrinkage measurements.

- Dye-penetrant testing (PT) of the weld overlay surface and one inch of base metal on either side of the weld overlay.

- Ultrasonic examination (UT) of the weld overlay deposit for general weld quality and "bonding" to the base metal. This UT will disclose evidence of any flaw which was not properly repaired or missed.

Based on the above discussion it is concluded that all of the design requirements contained in NRC Generic Letter 84-11 are followed in the Quad Cities 1 weld overlays. In addition, the application program in use at Quad Cities 1 far exceeds the "minimum" requirements of Generic Letter 84-11 in assuring that the weld overlay is an effective barrier against crack propagation and is of the highest quality possible. This assurance is accomplished through a combination of metallurgical, materials and welding controls coupled with extensive nondestructive examinations.

UT Inspection Results - 1982 vs 1984 Comparison

A total of 138 IGSCC-susceptible welds were inspected during the current Spring 1984 outage at Quad Cities Unit 1, including 10 jet pump instrument nozzle welds. These welds were all inspected utilizing the Commonwealth Edison inspection procedure by Lambert, McGill, and Thomas (LMT) personnel qualified in accordance with IE Bulletin 83-02 requirements. In addition, the Commonwealth Edison System Materials Analysis Department (SMAD) reviewed all data and made the final determination. Universal Testing Laboratories/Kraftwerke Union (UTL/KWU) was utilized as required to evaluate circumferential flaws and any other questionable indications.

During the Fall 1982 outage a total of 28 welds were inspected by United States Testing Laboratories utilizing the Commonwealth Edison procedure. SMAD also reviewed all data and made the final determination.

Of the 28 welds inspected during the 1982 outage, a total of 19 were reinspected during the 1984 outage. In no instance was a flaw found in a weld reinspected during the 1984 outage. This excellent correlation of inspection results leads to the conclusion that the examination/evaluation process being utilized by Commonwealth Edison produces consistent, reproducible results.

Leaking Axial Through-Wall Flaw Summary

As has been noted at previous outages, both at Commonwealth Edison plants and throughout industry, several welds evidenced leakage of primary coolant. The weld identification designations for the nine welds found to be leaking are given below:

02B-S7	02J-S4
02G-S3	02J-F6
02H-S3	02K-S3
02H-S4	02K-S4
02J-S3	

The flaw characterization for each is given in the tabulation "Quad Cities Unit 2 IGSCC Flaw Disposition Summary" (Attachment 1 to NUTECH Letter RHB-84-032).

In all nine cases the leakage observed occurred in a weld having an axial flaw. The leakage rate itself was very small; it might best be described as "weeping" rather than "leaking". No leakage was observed during plant operation, but instead occurred after weld preparation for IHSI or overlay application. In no case did the observed through-wall axial flaw represent a structural or safety hazard.

Quad Cities Unit 1
Sampling Plan for IGSCC Weld Inspection

The sampling plan for the Quad Cities Unit 1 outage conducted during Spring, 1984 was based on SECY-83-267C which is in agreement with Generic Letter 84-11. The SECY and Generic Letter basically require a 20% inspection sample each of "not inspected previously" and "inspected previously" welds with certain minimums. The inspection applies to stainless steel welds, susceptible to IGSCC, in piping equal to or greater than 4" in diameter in systems operating over 200° that are part of or connected to the reactor coolant pressure boundary out to the second isolation valve.

Induction Heating Stress Improvement (IHSI) was to be applied to welds in the recirculation system and in the Shutdown Cooling and LPCI lines up to the first isolation valves. Each of the IHSI treated welds was to receive an ultrasonic examination (UT) following treatment. Considering only the IHSI treated welds, approximately 80% of the recirculation system welds would receive UT examination.

A review of UT examination results of the latest Dresden 2 and 3 and Quad Cities 2 outages, as well as other utility experience, indicated cracking was not being experienced at nozzle-to-safe end welds (other than in furnace sensitized safe ends). The nozzle-to-safe end welds were not in the IHSI scope.

The recirculation inlet nozzle-to-safe end welds are in a high radiation area (approximately 1 to 1.5 R/Hr at QC1) requiring an expenditure of approximately 5 man-rem per weld examination. Considering the high probability of finding IGSCC in the inlet elbows, the UT sample of the inlet piping would likely expand to include all of the inlet nozzle-to-safe end welds if they were included in the 12" category. Based on cracking experience and Alara considerations, it was decided to make the recirculation inlet nozzle-to-safe end welds a sub-category of the riser piping welds subject to a separate sample expansion if IGSCC were found. Similar sub-categories were established for the recirculation outlet nozzle-to-safe end welds and the sweepolet-to-header welds (which are identified as being solution annealed). The sampling plan was provided to the NRC on March 19, 1984.

The sampling plan for the residual heat removal and core spray systems was determined by establishing groupings of previously inspected and not previously inspected welds and applying the rules of SECY-83-267C to arrive at the required numbers of welds. The welds selected were strongly biased to the highest temperature portions of these systems. All accessible 4" and larger welds susceptible to IGSCC were examined on the reactor water cleanup, head vent, and control rod drive return systems.

The jet pump instrument safe ends and attached assemblies had not been classed as piping systems, and were not included in the previously submitted sampling plan. Because of recent domestic BWR experiences with cracking in these safe ends and assemblies, inspections were performed with no indications of IGSCC being found.

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