February 15, 1984

Docket No. 50-265

Mr. Dennis L. Farrar
Director of Nuclear Licensing
Commonwealth Edison Company
Post Office Box 767
Chicago, Illinois 60690

Dear Mr. Farrar:

SUBJECT: ORDER CONFIRMING CECo COMMITMENT RE IGSCC INSPECTION

Re: Quad Cities Nuclear Power Station, Unit 2

The Commission has issued the enclosed subject Order related to intergranular stress corrosion cracking (IGSCC) inspection and repair for the Quad Cities Nuclear Power Station, Unit 2.

A copy of this Order is being filed with the Office of the Federal Register for publication. Also enclosed is a copy of the Commission's Safety Evaluation.

Sincerely,

Orginal Signed by /
Domenic B. Vassallo, Chief
Operating Reactors Branch #2
Division of Licensing

Enclosure:
1. Confirmatory Order
2. Safety Evaluation

cc w/enclosures:
See next page

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Mr. Dennis L. Farrar
Commonwealth Edison Company
Quad Cities Nuclear Power Station, Units 1 and 2

cc:

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
COMMONWEALTH EDISON COMPANY	)	Docket No. 50-265
	)	
(Quad Cities Nuclear Power Station, Unit 2)	)	

ORDER CONFIRMING COMMONWEALTH EDISON COMPANY'S COMMITMENTS RE IGSCC INSPECTION

I.

The Commonwealth Edison Company, (CECo, the licensee) is the holder of Facility Operating License No. DPR-30, which authorizes the licensee to operate the Quad Cities Nuclear Power Station, Unit 2 (the facility) at power levels not in excess of 2511 megawatts thermal (rated power). The facility is a boiling water reactor located at the licensee's site in Rock Island County, Illinois.

II.

As a result of inspections conducted at 18 operating boiling water reactors (BWRs) in conformance with recent Office of Inspection and Enforcement (IE) Bulletins (IE Bulletin No. 82-03, Revision 1, "Stress Corrosion Cracking in Thick-Wall, Large-Diameter, Stainless Steel, Recirculation System Piping at BWR Plants," and IE Bulletin No. 83-02, "Stress Corrosion Cracking in Large-Diameter Stainless Steel Recirculation System Piping at BWR Plants"), a potential safety concern regarding intergranular stress corrosion cracking (IGSCC) in primary system piping was identified. These bulletins requested selected licensees to perform a number of actions regarding inspection and testing of pipe welds.

Results of these and other inspections pursuant to IE Bulletins 82-03 and 83-02 have revealed extensive cracking in large-diameter recirculation and residual heat removal system piping. In almost every case, where inspections were performed, IGSCC was discovered and, in many cases, repairs, analysis, and additional surveillance conditions were required. In view of the foregoing and the fact that the facility is similar in design to plants where IGSCC has occurred, there was a significant potential for IGSCC to exist in this facility. Therefore inspection was required to determine the extent of IGSCC and to ascertain, if necessary, the degree of remedial action.

On August 26, 1983 an Order was issued to the licensee which required that the facility be shutdown by September 4, 1983 and an IGSCC inspection be performed. The facility was shutdown on September 4, 1983 pursuant to Section III.B of the Order and an IGSCC inspection was performed pursuant to Section III.C of the August 26, 1983 Order.

By letter dated December 9, 1983, the licensee provided its plan for inspection and repair of welds covered by the Order of August 26, 1983. The plan provided that, to the extent practicable, the ultrasonic testing (UT) program of examination would encompass 100% of the Type 304 Stainless Steel piping welds of 4-inch and greater size in the recirculation system and the ASME Code Class 1 portions of the residual heat removal systems, core spray external to the reactor pressure vessel and the reactor water cleanup system. Specific welds which were not to be inspected were identified, and explanations for their exclusion, had previously been provided in the licensee's letter of September 30, 1983. On December 20, 1983 and

January 5, 1984 the staff met with the licensee to discuss its program and its findings, and to receive clarifying information. By letter of January 19, 1984, the licensee submitted its final report on the inspection and repair of welds covered in the Order of August 26, 1983.

The NRC staff has reviewed and evaluated all the above reports and information provided by the licensee. That review is documented in our Safety Evaluation dated February 15, 1984. By letter dated February 15, 1984, the NRC notified the licensee that the facility could be returned to power.

Although the calculations performed by the licensee and evaluated by the staff indicate that the cracks in the repaired and unrepaired welds will not progress to the point of leakage during the operating cycle, and wide margins are expected to be maintained over crack growth which could compromise safety, uncertainties in crack sizing and growth rate remain. Because of these uncertainties, we have determined that the following actions should be taken:

(1) The ASME Code-required system pressure tests and nondestructive examinations on overlay repaired welds should be satisfactorily completed prior to startup.

(2) The limiting conditions for operation and surveillance requirements imposed by the August 26, 1983 Order should be continued. These enhanced surveillance measures will provide adequate assurance that possible cracks in pipes will be detected before growing to a size that will compromise the safety of the plant.

The staff also has some concern regarding the long-term growth of IGSCC cracks and its effect on the long-term operation of the plant. Therefore, we have determined that plans for inspections, corrective action and/or modification including replacement of the recirculation and other reactor coolant pressure boundary piping systems during the next refueling outage must be submitted at least 90 days before the start of the next refueling outage.

By letter dated February 8, 1984, the licensee committed to the above described conditions on leakage monitoring and early submittal of inspection and/or modification plans. I have determined that the public health and safety requires that these commitments should be confirmed by an immediately effective Order.

III.

Accordingly, pursuant to sections 103, 161i, 161o and 182 of the Atomic Energy Act of 1954, as amended, and the Commission's regulations in 10 CFR Parts 2 and 50, IT IS HEREBY ORDERED EFFECTIVE IMMEDIATELY THAT:

A. Notwithstanding the current Technical Specifications for the facility the following compensatory measures shall be implemented:

   1. The reactor coolant system leakage shall be limited to a 2 gpm increase in unidentified leakage within any 24 hour period

(leakage shall be monitored and recorded once every 4 hours). Should this leakage limit be exceeded, the unit shall immediately start an orderly shutdown. The unit shall be placed in at least hot shutdown within the next 12 hours and in cold shutdown within the following 24 hours.

2. At least one primary containment sump collection and flow monitoring system shall be operable. With the primary containment sump collection and flow monitoring system inoperable, restore the inoperable system to operable status within 24 hours or immediately initiate an orderly shutdown and be in at least hot shutdown within the next 12 hours and in cold shutdown within the following 24 hours.

B. Plans for inspection, corrective actions, and/or modification, including replacement of the recirculation and/or coolant pressure boundary piping systems, during the next refueling outage which is scheduled to begin in September 1985 shall be submitted at least three months before the start of that outage.

C. The Director, Division of Licensing, may, in writing, relax or terminate any of the above provisions upon written request from the licensee, if the request is timely and provides good cause for the requested action.

IV.

The licensee may request a hearing on this Order within 20 days of the date of publication of this Order in the Federal Register. Any request for a hearing shall be addressed to the Director, Office of Nuclear Reactor Regulation, U. S. Nuclear Regulatory Commission, Washington, D. C. 20555. A copy shall also be sent to the Executive Legal Director at the same address. A REQUEST FOR HEARING SHALL NOT STAY THE IMMEDIATE EFFECTIVENESS OF THIS ORDER.

If a hearing is to be held, the Commission will issue an Order designating the time and place of any such hearing.

If a hearing is held concerning this Order, the issue to be considered at the hearing shall be whether, on the basis of the matters set forth in Section II of the Order, the licensee should comply with the requirements set forth in Section III of this Order. This Order is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Darrell G. Eisenhut

Darrell G. Eisenhut, Director
Division of Licensing
Office of Nuclear Reactor Regulation

Dated at Bethesda, Maryland
this 15th day of February, 1984.

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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO INTERGRANULAR STRESS CORROSION CRACKING

COMMONWEALTH EDISON COMPANY
AND
IOWA-ILLINOIS GAS AND ELECTRIC COMPANY

QUAD CITIES NUCLEAR POWER STATION, UNIT 2

DOCKET NO. 50-265

INTRODUCTION

Quad Cities Unit 2 was shut down on September 4, 1983 in accordance with the confirming order issued on August 26, 1983 to inspect all ASME Class 1 austenitic stainless steel piping that are susceptible to intergranular stress corrosion cracking (IGSCC) in the Recirculation, Residual Heat Removal (RHR), Core Spray and Reactor Water Clean-up (RWCU) systems. During this shutdown period, ultrasonic examinations were performed on 225 nonconforming welds. Of these, 120 welds were in the Recirculation system, 64 welds were in the RHR system, three (3) welds were in the RWCU systems, 25 welds were in the Core Spray (CS) system, 12 welds were in the Control Rod Drive (CRD) system and one (1) was a Head Vent weld. The licensee, Commonwealth Edison Company (CECO), indicated that except for 10 welds, all Class 1 welds susceptible to IGSCC in the above mentioned piping systems were ultrasonically examined. The 10 welds (6 RHR welds, 2 CS welds and 2 RWCU welds) cannot be ultrasonically examined because of access limitations.

Personnel from Lambert, McGill, and Thomas (LMT) performed the ultrasonic testing (UT) for the licensee. All LMT reported crack indications were confirmed by CECO's UT personnel. 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 83-02, and the same procedures and techniques were used in the UT examination. Region III also indicated that all their UT personnel conducting these inspections have received appropriate training in IGSCC inspection using cracked thick-wall pipe specimens. LMT used 45° and 60° shear waves for crack detection and 25% leading and trailing movement for crack depth measurement. The results of the UT examinations indicated that a total of 23 welds showed reportable linear indications. Of these, eleven are 28" Recirculation welds, two are 22" Recirculation Manifold welds, seven are 12" Recirculation Riser welds, two are 20" RHR welds, and one is 6" RWCU weld.

All reported UT indications were in the weld heat-affected-zone (HAZ). Of the 23 defective welds, six (6) welds were reported to have a crack depth over 25% of the wall thickness. The majority of the cracks in the defective welds were in the circumferential direction. The deepest circumferential crack with a depth of 80% of the wall thickness was reported in a 12" Riser weld (02D-F6). Short axial cracks were reported in two 28" Recirculation welds. The reported crack length in all defective welds varied from half of an inch to 360° intermittently along the circumference. Five (5) defective welds were reported to have a crack length at least 120° of the circumference. As will be discussed later, International Test Laboratory (ITL) and Universal Testing Laboratory (UTL) performed supplementary UT examinations on those five (5) welds using advanced techniques. Based on the results of the advanced UT techniques, UTL determined that these five (5) welds were not cracked. Subsequently, the "worst" of the five (5) welds (28S-S12) was confirmed to be not cracked by destructive metallography and radiography examinations.

General Electric (GE) performed Induction-Heat-Stress-Improvement (IHSI) for the licensee on a total of 87 welds (77 Recirculation welds and 10 RHR welds) including all the unrepaired defective welds. The licensee indicated that all the large size (> 12 inches) stainless steel piping welds in the Recirculation and RHR systems up to the first isolation valves were treated with IHSI except the bimetallic welds, eight (8) sweepolet welds, three (3) overlay repaired welds and nine (9) welds requiring special heating coils because of geometry. UT inspection was performed on each weld after IHSI. 38 IHSI treated welds were also UT inspected prior to IHSI. There are no significant differences in UT results before and after IHSI. Region III of the NRC indicated that IHSI was satisfactorily performed in accordance with the qualified GE procedures.

Based on a review of the UT data and the IHSI record, the licensee decided to weld overlay repair six (6) defective welds. Of these, two (2) welds had axial cracks, three (3) welds had circumferential cracks with depth over 30% of the wall thickness and one (1) weld was improperly treated with IHSI. In addition, one (1) RWCU weld (12S-S27) was replaced with low carbon stainless steel piping material.

NUTECH performed flaw evaluations on the remaining 17 defective welds for the licensee to determine whether overlay repair is needed or not. The evaluations were based on the methodology provided in the new ASME Code Section XI IWB-3600. The new Code IWB-3600 provides flaw acceptance criteria for the austenitic stainless steel piping based on a limit load approach which was approved by the ASME Main Committee in May 1983 and was published in Winter 1983 Addenda. The results of NUTECH's flaw evaluations, including crack growth calculations, indicated that all the remaining 17 defective welds did not require weld overlay repair because the calculated flaw sizes of those 17 welds at the end of an 18-month period did not exceed the staff's criteria of two-thirds of the new Code allowable limits. In NUTECH's calculations, the cracks in each weld were essentially arrested by the surrounding compressive residual stresses induced by the IHSI treatment.

We had some concerns regarding five (5) extensively cracked welds (2 12" Riser welds, 02F-F6 and 02J-F6, and 3 28" Recirculation welds, 02AS-F14, 02BS-F7 and 02BS-S12) which were not recommended to be overlay repaired. The crack length in each of these five (5) welds is long and encompasses at least 120° of the circumference. After several discussions with the licensee regarding our concerns, the licensee brought in ITL and UTL to perform additional UT examinations on the five (5) welds. Both ITL and UTL used the techniques of 45° and 60° shear wave, crack tip diffraction and OD creeping wave to size the crack depth. UTL also used an advanced technique based on ID creeping wave to detect the shallow cracks. The creeping wave is reported to be transparent to the metallurgical reflectors such as the fusion line. The indications reported by ITL and UTL based on the use of 45° and 60° shear wave were similar to that reported by LMT. However, based on the results of using ID creeping wave, UTL determined that these five (5) welds were not cracked and the indications were from metallurgical reflections. To confirm UTL's determination, a trepan sample about one inch in diameter was taken from one of the five welds (2BS-S12, 28" Recirculation weld) at the location reported to have the strongest crack indication. No cracks were found from the trepan sample both visually and destructively (metallographic examination). Single wall radiography was also performed on weld 2BS-S12 and no crack indication was found. In the meantime, the licensee decided to weld overlay three (3) (2 12" Riser welds, 02F-F6 and 02J-F6, and 1 28" Recirculation weld, 02BS-F7) of the five (5) welds to ensure that the required Code safety margin would be maintained during operation.

NUTECH also performed weld overlay design for the licensee. Nine (9) defective welds (4 12" Riser welds, 4 28" Recirculation welds and 1 20" RHR weld) were weld overlay repaired. The overlay thickness was designed to meet the new IBW-3600 limits based on an assumed crack depth which is two times the reported maximum crack depth. The length of the overlay was selected to reinforce the weld structure and minimize the end effects. The as-build overlay thickness was reported to vary from 0.27 inch to 0.462 inch and the as-built overlay length was reported to vary from 2.8 inches (only one side) to 6.5 inches. Region III of the NRC has confirmed that the weld overlay repairs were performed in accordance with the qualified and approved procedures consistent with ASME Code requirements.

The licensee reported that the as-measured axial shrinkages from the nine (9) overlay repaired welds were in the range of 0.019 inch to 0.23 inch. The stresses caused by this shrinkage on all the unrepaired defective welds were calculated. The largest value was reported to be 8,400 psi on a 12" Riser weld (02D-S3). In NUTECH's crack growth calculation, the shrinkage stresses due to weld overlay were considered.

In summary, during the current Quad Cities Unit 2 confirming order outage, a total of 225 nonconforming austenitic stainless steel welds were UT examined. This includes all the UT examinable stainless steel welds in the Recirculation, RHR, Core Spray, RWCU and CRD piping systems. In addition, 87 welds were treated with IHSI including all the unrepaired defective welds. The UT results reported by LMT indicated that 23 welds showed reportable linear indications. Of these, nine (9) welds were overlay repaired, one (1) weld was replaced and one (1) weld was shown not to be cracked by metallography and radiography examinations.

EVALUATION

We reviewed the licensee's submittals, including NUTECH's analysis of the weld overlay designs, and the calculation of IGSCC crack growth nine (9) overlay repaired welds, the 12 IHSI mitigated defective welds (3 12" Riser welds, 6 28" Recirculation welds, 2 22" manifold welds and 1 20" RHR weld) and one (1) replaced weld (6" RWCU weld).

NUTECH used the favorable residual stress distribution resulting from IHSI treatment in their IGSCC crack growth calculations, because each unrepaired defective weld was mitigated by IHSI. The results of NUTECH's calculations indicated that the cracks were essentially arrested in every IHSI treated weld. This is caused by the presence of large compressive residual stresses at the front of the crack tip. NUTECH indicated that the reported crack depth in each unrepaired defective weld is well within the staff's criterion of two-thirds of the new Code allowable limits.

We reviewed NUTECH's IGSCC crack growth calculations and agree with their conclusion that the continued operation for an 18-month fuel cycle with the 12 defective welds mitigated by IHSI is justified because the Code design safety margin would be maintained. Our conclusion is based on the following considerations:

(1) Overcalls in UT Examination

The UT indications reported by LMT were based on the technique of using 45° and 60° shear wave. The shear wave technique does not have the capability of discriminating the indications reflected from a crack and that from a metallurgical reflection. This was clearly demonstrated by UTL's test results of weld 28S-12S using advanced UT techniques. LMT's inspection results indicated that weld 28S-12S was extensively cracked; however, UTL determined that weld 28S-12S was not cracked and this was confirmed by the destructive metallography and radiography examinations. Therefore, we expect additional overcalls might be present in the LMT's test results. It is possible that some of the welds reported by LMT to be defective may not be cracked or, if it is cracked, it may not be cracked to the extent as reported.

(2) Short Cracks

Of the 23 welds reported by LMT to be defective, nine (9) welds were overlay repaired, one (1) weld was replaced and two (2) welds were determined by UTL to be not cracked. In the remaining 11 defective welds, six (6) welds have relatively short cracks with a crack length not exceeding 29° of the circumference and the other five (5) welds have crack length varied from 45° to 100° of the circumference. Based on limit load analysis and the stress ratio reported by NUTECH, even if the cracks were assumed through-wall, it will not have a significant effect on the structural integrity of the welds.

(3) IHSI Mitigation

The licensee indicated that all the unrepaired defective welds were mitigated by the IHSI process. IHSI is a process developed in Japan for treating weldments already fabricated or installed in a plant system. It consists of heating the outside of the pipe by induction coils to controlled temperatures (~ 800°F) while cooling water is circulated inside the pipe. The high thermal gradients produce the same effect as Heat Sink Welding (HSW). The inside of the pipe is stretched during the process, causing high residual compressive stresses after the process is completed.

In the proposed NUREG 0313, Revision 2, the staff has accepted the IHSI as an effective IGSCC mitigation process when applied to uncracked welds because there is concern regarding the effectiveness of IHSI process when applied to cracked welds especially for deep cracks (≧ 50% of the wall thickness). This concern is compounded by the uncertainties associated with the UT determination of the crack depth. Therefore, at this time, we will consider the IHSI mitigation on welds with shallow cracks as a temporary fix. The Japanese have reported some limited field experience of applying IHSI to cracked weld in an EPRI sponsored seminar of counter-measures for BWR pipe cracking. In Fukushima I, Unit 3, IHSI was applied to five (5) cracked sweepolet welds in the Recirculation piping system. After one year's operation, the results of UT examination indicated that the cracks in the five (5) sweepolet welds did not propagate.

The licensee replaced one (1) defective RWCU weld (12S-S27) with 304L (SA 304, Grade WP, 304L) stainless steel material using HSW. 304L stainless steel material is considered resistant to IGSCC, and HSW produces favorable compressive residual stresses at the inner surface further inhibiting IGSCC initiation and growth. Therefore, we conclude that the replaced defective weld is acceptable for continued service.

NUTECH's overlay design for the nine (9) defective welds was based on assuming the crack depth to be two times the reported maximum crack depth. The favorable residual stress distribution resulted from weld overlay repair is depended upon to inhibit further crack growth. The residual stress distribution used in their analyses was calculated using a finite element model. The required overlay thickness determined this way is much thinner than that determined by assuming all cracks are completely through-wall. Although there are many important advantages in using thin overlay (lower fabrication time and cost, less radiation exposures, increased UT inspectability of the overlaid weld, and less distortion in the piping system), the thinner overlays do not provide complete Code compliance if the cracks were to continue to grow until it reaches the overlay.

The specific residual stress distribution used by NUTECH in this analysis appears to us to be somewhat more favorable than can be justified at this time; therefore, for our analysis, we relied on distributions derived from later work, and results from closely related work performed under EPRI contracts. Even with our more conservative approach, we also concluded that all repairs will provide adequate assurance of safe operation during the next operating cycle.

There are 10 welds (6 RHR welds, 2 CS welds and 2 RWCU welds) not examinable by UT because of access limitations. Of these, eight (8) are containment penetration welds, one (1) is a reinforced RWCU branch weld surrounded by a saddle weld, and one (1) is a Head Spray weld located in a water barrier between the Drywell and the Reactor Cavity. The licensee indicated that all eight (8) containment penetration welds are isolable; however, the 6" RWCU branch weld and the 4" Head Spray weld are not isolable. During normal plant operation, there is no flow in the Head Spray piping and the temperature is less than 200°F. Therefore, we do not expect this Head Spray weld to be extensively cracked. The non-isolable RWCU weld is made of small piping (6" diameter) and leakage in this size of piping is not expected to create any major LOCA, because the leakage is expected to be within the reactor coolant make-up capacity and can be detected by the leak detection system. We conclude that the 10 uninspected welds will not create any major safety problem during the continuous operation of the unit for a normal operating cycle.

Leak Detection

Although the conservative calculations discussed above indicate that the cracks in the unreinforced welds will not progress to the point of leakage during the operating fuel cycle, 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. Further, not all welds were UT examinable, and cracks could be present in welds that were not examined. Because of these uncertainties, it is prudent to tighten the requirements for the monitoring of unidentified leakage.

The licensee has agreed to additional monitoring and tighter limits on unidentified leakage, which are summarized below:

(1) The reactor coolant system leakage will be limited to a 2 gpm increase in unidentified leakage within any 24 hour period. Leakage shall be monitored and recorded once every 4 hours. Should this leakage limit be exceeded, the unit will immediately start an orderly shutdown. The unit will be placed in at least hot shutdown within the next 12 hours and in cold shutdown within the following 24 hours.

(2) At least one (1) primary containment sump collection and flow monitoring system will be operable. With the primary containment sump collection and flow monitoring system inoperable, restore the inoperable system to operable status within 24 hours or immediately initiate an orderly shutdown and be in at least hot shutdown within the next 12 hours and in cold shutdown within the following 24 hours.

We conclude that implementation of the above measures will provide adequate assurance that possible cracks in pipes will be detected before growing to a size that could compromise the safety of the plant.

SUMMARY AND CONCLUSIONS

We have reviewed CECO's submittals regarding the actions taken or to be taken during this refueling outage on the inspection, analyses and repairs of Recirculation, RHR, RWCU, Core Spray, Head Spray and CRD piping systems in the Quad Cities Unit 2 plant. This includes a description of the defects found, description of repairs, stress and fracture mechanics analysis.

We conclude that the Quad Cities Unit 2 plant can be safely returned to power and operated in its present configuration at least for one normal operating cycle provided that the following items are satisfactorily completed:

(1) The Code required system pressure tests and nondestructive examinations on overlay repaired welds should be satisfactorily completed prior to startup.

(2) The additional leak detection requirements as listed in the section on Leak Detection should be in place prior to startup.

Nevertheless, we still have concern regarding the long term growth of small IGSCC cracks that may be present but not detected during this inspection. Therefore, plans for inspection and/or modification of the recirculation and other RCPB piping systems during the next refueling outage should be submitted for NRC review at least three (3) months before the start of the next refueling outage.

Principal Contributors: W. Koo and W. Hazelton

Dated: February 15, 1984