June 6, 2002

Mr. John L. Skolds, President
Exelon Nuclear
Exelon Generation Company, LLC
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNIT 2 - APPROVAL OF PIPE FLAW EVALUATION (TAC NO. MB4093)

Dear Mr. Skolds:

By letter dated February 22, 2002, as supplemented February 26 and March 14, 2002, Exelon Generation Company, LLC (EGC), the licensee, submitted a request for NRC review and approval of a pipe flaw evaluation for a weld in the reactor recirculation system piping at Quad Cities Nuclear Power Station, Unit 2, that you proposed to leave as-is without repair. A flaw in weld No. 02BD-F9 was found during the recent Unit 2 refueling outage while conducting inspections in accordance with U.S. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 88-01/Boiling Water Reactor Vessel and Internals Project (BWRVIP) Report 75, "Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules." The flaw did not meet the acceptance standards of American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (Code) Section XI, 1989 Edition, for continued operation without evaluation. In accordance with GL 88-01, identified cracks that do not meet the criteria given in ASME Code Section XI for continued operation without evaluation require NRC approval of the flaw evaluation and/or repairs in accordance with subarticles IWB 3640 and IWA 4130 before resumption of operation.

You performed the flaw evaluation using the methodology and acceptance criteria specified in ASME Code, Section XI, 1989 Edition, subarticle IWB-3640, "Evaluation Procedures and Acceptance Criteria for Austenitic Piping," and the guidance of NUREG-0313, Revision 2, "Technical Report on Material Selection and Process Guidelines for BWR [boiling water reactor] Coolant Pressure Boundary Piping." Your evaluation was submitted to the NRC for approval prior to resuming operation in accordance with GL 88-01, "NRC Position on IGSCC [intergranular stress corrosion cracking] in BWR Austenitic Stainless Steel Piping."

Following its review of your submittal, the staff has determined that your evaluation is acceptable. Based on your letter dated February 22, 2002, as supplemented February 26, 2002, and additional information provided in conference calls on February 27, 28, and March 1, 2002, the staff provided verbal approval on March 1, 2002, of your pipe flaw evaluation in accordance with GL 88-01. Subsequently, you provided supplemental information supporting your request for approval of pipe flaw evaluation by letters dated March 14 and April 30, 2002. The enclosed safety evaluation provides the details of the staff's conclusions on this issue.

If you have any questions regarding this matter, please call me at (301) 415-2296.

Sincerely,

/RA/

Carl F. Lyon, Project Manager, Section 2
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No.: 50-265

Enclosure: Safety Evaluation

cc w/encl: See next page

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Carl F. Lyon, Project Manager, Section 2
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Enclosure: Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR APPROVAL OF PIPE FLAW EVALUATION FOR A

CIRCUMFERENTIAL CRACK IN THE B-LOOP RECIRCULATION PIPE WELD

QUAD CITIES NUCLEAR POWER STATION, UNIT 2

EXELON GENERATION COMPANY, LLC

DOCKET NO. 50-265

1.0 INTRODUCTION

By letters dated February 22, February 26, March 14, and April 30, 2002, the Exelon Generation Company, LLC (the licensee), submitted for U.S. Nuclear Regulatory Commission (NRC) review its evaluation of a circumferential crack in a weld in the B-loop reactor recirculation piping for Quad Cities Nuclear Power Station (Quad Cities), Unit 2. The pipe is 28 inches in diameter with a nominal wall thickness of 1.4 inches, and the pipe material is austenitic stainless steel. The weld was fabricated using the shielded metal arc weld (SMAW) process. The crack was discovered by ultrasonic (UT) examination on February 17, 2002, during the Q2R16 refueling outage and determined to be 10 inches long and 0.56 inch deep. The licensee intended to demonstrate through an analytical flaw evaluation using a reduced crack growth rate corresponding to operation with hydrogen water chemistry (HWC) that the unit could be operated for one fuel cycle without repair of the subject weld.

2.0 EVALUATION

2.1 Licensee

2.1.1 Crack Growth Rate

Based on the hydrogen availability during the past year, the licensee projected that the HWC operation would be effective 90 percent of the time during the next fuel cycle. Consequently, the licensee used a reduced crack growth rate (CGR) of 1.1×10^{-5} inch/hour for this portion of the cycle, as permitted by the NRC safety evaluation (SE) dated December 3, 1999, on BWRVIP-14, “BWR Vessel and Internals Project, Evaluation of Crack Growth in BWR Stainless Steel Internals (BWRVIP-14).” For the remaining 10 percent of the cycle, the licensee used a CGR of 2.2×10^{-5} inch/hour to reflect water chemistries with a conductivity of $\leq$ 0.15 µS/cm and an electrochemical potential of +200 mV. This results in a crack growth of 0.21 inch in a fuel cycle. Adding this to the initial crack depth of 0.56 gives a maximum depth of 0.77 inch at the end of one cycle. For the length direction, however, the licensee determined that the final length at the end of one cycle is 19 inches, which is obtained by multiplying the initial crack length by the square of the ratio of the final depth to the initial depth.

2.1.2 Flaw Evaluation - Limit Load Analysis

The licensee used the procedures of Appendix C, "Evaluation of Flaws in Austenitic Piping," of Section XI of the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (Code) to perform a limit load analysis for the flawed pipe at the end of one cycle. The loading that was considered in the limit load analysis included gravity, pressure, thermal, operating-basis earthquake (OBE), and design-basis earthquake (DBE). The stress intensity, S_m, is 16.9 ksi, while the Z factor was calculated by the licensee to be 1.51 for the SMAW weld. Instead of calculating the allowable flaw depth and length using the Code specified safety factor of 2.77 for the normal and upset conditions and 1.39 for the emergency and faulted conditions, the licensee calculated the safety factors associated with the final crack geometry. This approach results in a safety factor of 5.09 for the normal and upset conditions and 4.59 for the emergency and faulted conditions. Since the calculated safety factors are greater than the code specified values, the licensee concluded that the flawed weld of the B-loop recirculation piping meets the structural margin requirements for continued operation after Q2R16 for one fuel cycle.

2.1.3 IGSCC Resistance of the Cast Stainless Valve Body Next to the Cracked Weld

The licensee reported four ferrite content measurements in the cast austenitic stainless valve that were taken approximately 3 to 4 inches from the flawed weld. These measurements all indicated ferrite contents greater than 10 ferrite number (FN). The upper bound carbon content for the valve material was reported to be 0.06 percent. To demonstrate the intergranular stress-corrosion cracking (IGSCC) resistance of this valve material, the licensee cited General Electric Company (GE) data from IGSCC tests on castings with different carbon content and ferrite numbers. The GE experience shows that the cast austenitic stainless material with a FN of 10 and a carbon content of 0.06 percent would be IGSCC resistant. Based on this, the licensee determined that the valve body is IGSCC resistant.

2.1.4 Hydrogen Water Chemistry Program

The licensee implemented a HWC program at the Quad Cities units in 1990. Noble metal chemical addition (NMCA) was applied in 2000 to further enhance the HWC program. The average availability of the HWC was reported to be greater than 90 percent during the past three years. The conductivity was maintained below 0.15 uS/cm. The electro-chemical potential (ECP) was measured hourly. The average ECP had been reported to be approximately -490 mV (standard hydrogen electrode, SHE) at both units. The ECP was measured at the reactor water cleanup (RWCU) system piping flange near the first heat exchanger from the reactor. The licensee stated that the flow at this location is more oxidizing than that of the recirculation flow because it consists of both recirculation and bottom head flow. The HWC program implemented at the Quad Cities units also has a noble metal durability monitoring system. Coupons (tubing pieces) were removed from the system for analysis every six months to determine the adequacy of noble metal deposition. The results of the analysis from the withdrawn coupons demonstrated that sufficient noble metal deposition will be available during the next 24-month fuel cycle.

2.2 NRC Staff

2.2.1 Crack Growth Rate

The conditions for using the CGR of 2.2 x 10^{-5} inch/hour are specified in BWRVIP-14 and the corresponding NRC SE dated December 3, 1999. The use of the CGR of 1.1 x 10^{-5} inch/hour is allowed when an effective HWC or NMCA program is maintained. The criteria for an effective HWC or NMCA program are identified in open item 3.2 of the NRC SE dated January 30, 2001, for BWRVIP-62, "BWR Vessel and Internals Project, Technical Basis for Inspection Relief for BWR Internal Components with Hydrogen Injection (BWRVIP-62)." The licensee's CGR of 2.2 x 10^{-5} inch/hour for 10 percent of the cycle, reflecting water chemistries with a conductivity of ≤ 0.15 µS/cm and an electrochemical potential of +200 mV, and CGR of 1.1 x 10^{-5} inch/hour for 90 percent of the cycle, reflecting the implementation of the NMCA and hydrogen injection, are acceptable, because they are in accordance with the NRC SE on BWRVIP-14. According to this SE, the above mentioned CGRs are only applicable to components with fluences less than 5.0 x 10^{20} n/cm^2. This fluence condition is easily met by the low fluence condition at the recirculation pipe weld.

2.2.2 Flaw Evaluation - Limit Load Analysis

The licensee's limit load analysis of the flawed pipe weld is in accordance with Appendix C of the ASME Code. The staff performed a hand calculation of the primary membrane and bending stresses based on the provided piping loads and confirmed that the licensee's input stresses to the limit load analysis are conservative. The licensee's approach of calculating the safety factors associated with the final crack geometry is better than the conventional way of calculating the allowable flaw depth and length using the Code specified safety factor of 2.77 for the normal and upset conditions and 1.39 for the emergency and faulted conditions. The reason is that the licensee's approach only needs one parameter (the safety factor) to indicate margin, while the latter needs two parameters (the allowable crack depth and length). Since the calculated safety factor of 5.09 for the normal and upset conditions and 4.59 for the emergency and faulted conditions are greater than the corresponding Code specified values, the staff agrees with the licensee's conclusion that the flawed weld of the B-loop recirculation piping meets the structural margin requirements for continued operation for one fuel cycle. It should be mentioned also, that the licensee's calculation of the crack length in proportion to the square of the ratio for the crack depths at and before each calculating step is more conservative than that of NUREG-0313, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping." In this application, the licensee's approach gives an aspect ratio of 24.67 for the final crack geometry while NUREG-0313 specifies a bounding value of 20 for any crack geometry. Hence, there is additional conservatism in the licensee's analysis.

2.2.3 IGSCC Resistance of the Cast Stainless Valve Body Next to the Cracked Weld

NUREG-0313 specified 7.5 as the minimum value for FN and 0.035 percent as the maximum carbon content for cast austenitic stainless steel materials to be considered IGSCC resistant. The licensee's reported FN satisfies the required minimum value of 7.5, but the reported carbon content does not satisfy the required maximum value of 0.035 percent for IGSCC resistant cast austenitic stainless steel. However, the GE data in the submittal indicate that cast austenitic stainless steel with a FN of 10 and a carbon content of 0.06 percent is IGSCC resistant. Since the nuclear steam supply system (NSSS) vendor for Quad Cities Unit 2 is GE, the staff determined that using the GE IGSCC test data is acceptable. This is further supported by the field experience that there is no reported IGSCC in cast stainless steel materials of CF8 and CF8M for GE BWRs. Hence, the staff agrees with the licensee's determination that the valve body is IGSCC resistant.

2.2.4 Hydrogen Water Chemistry Program

The licensee's HWC program at Quad Cities Unit 2 is enhanced by the application of NMCA. The benefit of NMCA is confirmed by the measured ECP values, reported to be approximately -490 mV, which is significantly lower that the required -230 mV for an effective HWC. The licensee monitored the ECP hourly using a crack arrest verification (CAV) system. The reported availability of HWC over 90 percent of the operating time in the past three years exceeds the required 80 percent of the operating time for an effective HWC. Further, the ECP at the monitoring location would bound the ECP at the crack location due to the presence of a more oxidizing environment at the monitoring location. Based on the review of the licensee's HWC program, the staff has determined that the HWC program implemented at Quad Cities Unit 2 is effective because the subject program meets the criteria for an effective HWC program as delineated in the staff's SE on BWRVIP-75, dated September 15, 2002. Therefore, the licensee's use of a reduced CGR of 1.1×10^{-5} inch/hour in flaw evaluation for the period with an effective HWC condition is acceptable.

3.0 CONCLUSION

Based upon its review of the licensee's evaluation, the staff concludes that the licensee's flaw evaluation meets the rules in Section XI of the ASME Code. Since the safety factors associated with the detected crack are greater than those specified in the ASME Code, the staff concludes that Quad Cities Unit 2 can be operated for one fuel cycle without repair of the B-loop recirculation pipe weld.

Principal Contributors: S. Sheng
W. Koo

Date: June 6, 2002