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**MEMORANDUM TO:** Robert A. Capra, Director  
Project Directorate III-2  
Division of Reactor Projects III & IV

**FROM:** Edmund J. Sullivan, Jr., Section Chief *ENC for*  
Materials and Chemical Engineering Branch *8 Aug 97*  
Division of Engineering

**SUBJECT:** REVIEW OF BRAIDWOOD UNIT 1 STEAM GENERATOR 90 DAY  
REPORT (TAC No. M95339)

In a letter dated March 5, 1996 and supplemented by a letter dated March 8, 1996, the Commonwealth Edison Company (ComEd or the licensee) submitted its steam generator (SG) 90 Day report, "Braidwood Unit-1 Cycle 6 Interim Plugging Criteria 90 Day Report." The report summarized the results of the licensee's assessment of the eddy current (EC) inspection results with respect to the requirements established for voltage-based tube repair criteria.

The cycle-specific amendment approving the use of voltage-based repair criteria for this unit included a reporting threshold of  $1 \times 10^{-2}$  for the conditional probability of tube burst. The licensee's projections estimated a conditional burst probability below this threshold using NRC staff approved methodology. The estimates of the primary to secondary leak rate during a postulated main steam line break (MSLB) for Braidwood Unit 1 were below the maximum allowable accident leak rate of 26.8 gpm and were estimated by the licensee using NRC staff approved methodology. We conclude the licensee implemented the voltage-based repair criteria in accordance with its licensing basis. The staff's review of the report is attached.

Although the licensee implemented the voltage-based repair criteria in accordance with its licensing basis, concerns with the predictive methodology were brought out during recent meetings between ComEd and the NRC staff. ComEd and the staff met April 30 to discuss various aspects of the SG EC inspection performed during the Braidwood Unit 1 end-of-cycle 6 (EOC-6) spring 1997 refueling outage. At this meeting, ComEd compared the predictions for MSLB leak rate at the EOC-6 (these predictions are discussed in the attached review) with calculations based on actual inspection results. ComEd found the predicted MSLB leak rate was nonconservative with respect to the actual calculated leak rate although still within site allowable leak rate limits. ComEd attributed the nonconservative prediction

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to an unexpectedly high number of large (i.e., greater than 5 volt) ODSCC indications. In a subsequent meeting with the staff held July 23, the licensee reported larger indications in general grew at rates much faster than the rest of the voltage population. The methodology used to predict the EOC-6 voltage distribution did not consider such voltage-based growth rate variations; this resulted in a nonconservative prediction of the EOC-6 voltage distribution. The nonconservative prediction of voltage distribution in turn resulted in a nonconservative calculation of the MSLB leak rate.

In the same July 23 meeting, ComEd also discussed the assessment of the radiological consequences of a MSLB. The licensee indicated that for Braidwood-1, past comparisons were not conservative because the primary-to-secondary leakage attributed to SG tube indications is calculated based on models that use a room temperature volumetric leak rate measurement while the site allowable leak rate limit is calculated based on a mass flow rate measurement at accident conditions (e.g., high temperature). Because this issue potentially affects several other plants implementing the voltage-based SG tube repair criteria, the staff plans to address this issue generically.

ComEd will include its resolution of these issues in Braidwood Unit 1's Cycle 7 90 Day Report, expected to be submitted in August. The staff plans to review this report in a manner similar to the attached review, with particular emphasis on ComEd's evaluation and corrective action with respect to the predictive methodology and assessment of the radiological consequences of a MSLB.

We request you provide this review to ComEd.

Attachment: Review of Braidwood Unit 1 Steam Generator 90 Day Report

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## Review of Braidwood Unit 1 Steam Generator 90 Day Report

In a letter dated March 5, 1996, as supplemented by a letter dated March 8, 1996, Commonwealth Edison (ComEd or the licensee) submitted its steam generator (SG) 90 day report, "Braidwood Unit-1 Cycle 6 Interim Plugging Criteria 90 Day Report" [Reference 1]. The staff reviewed the submittal using criteria from References 2 and 3 and found the licensee's assessment to be acceptable. Details of the review are provided below.

### 1.0 General Plant Description

The Braidwood Nuclear Power Station Unit 1 (Braidwood-1) has four Westinghouse model D4 SGs with 3/4-inch diameter tubes. During the last refueling outage at the end-of-cycle (EOC) 5, ComEd implemented a 1.0 volt Interim Plugging Criteria (IPC) to be applied to outside diameter stress corrosion cracking (ODSCC) at the tube support plate (TSP) intersections on the cold leg side of the SGs and a 3.0 volt IPC to be applied to ODSCC at the TSP intersections on the hot leg side of the SGs, with certain exceptions. References 2 and 3 describe the 1.0 volt and 3.0 volt IPC methodologies in detail.

The licensee used a lower repair limit of 1.0 volt and determined an upper voltage repair limit of 1.99 volt to disposition ODSCC at TSP intersections on the cold leg side. The staff did not review the details of ComEd's basis for the upper voltage repair limit of 1.99 volt. Indications less than or equal to 1.0 volt were left in service, indications greater than 1.99 volt were removed from service, and indications with voltages between 1.0 and 1.99 volt were removed from service if confirmed with a rotating pancake coil (RPC) probe. ComEd used a repair limit of 3.0 volt to disposition ODSCC at TSP intersections on the hot leg side. Indications less than or equal to 3.0 volt were left in service while indications greater than 3.0 volt were removed from service.

### 2.0 Steam Generator Tube Eddy Current Inspection Scope and Results

ComEd inspected 100% of its SG tubes full length using a 0.610-inch diameter bobbin coil with the exception of one TSP intersection located on the cold leg side and present since initial startup. It is not adjacent to an expanded tube nor was an IPC applied to this TSP intersection.

For tubes where the 3.0 volt IPC was applied, the licensee used the RPC probe to inspect 20% of bobbin voltages between 1.0 and 3.0 volt and all bobbin voltages greater than 3.0 volt. For tubes where the 1.0 volt IPC is applied, the licensee used the RPC probe to inspect 100% of bobbin voltages greater than 1.0 volt.



ComEd also used the RPC probe to inspect all intersections with dent signals greater than 5.0 volt, a 20% sample of intersections with bobbin dent voltages between 2.5 and 5.0 volt, and all intersections with large mixed residuals. The licensee did not detect any indications. ComEd's RPC inspections confirmed no primary water stress corrosion cracking (PWSCC) or circumferentially oriented ODSCC existed at the TSPs. All ODSCC indications were within the confines of the TSPs. ComEd reported no signal interference from copper deposits at Braidwood-1. The licensee reported no corrosion induced dents in intersections adjacent to expanded tubes.

ComEd reported a total of 4136 ODSCC indications at TSP intersections and will return 4083 indications to service at Braidwood-1. Of the 53 indications removed from service, 38 indications were in tubes plugged for degradation mechanisms other than ODSCC at the TSPs. Of the remaining 15 indications, 14 were in tubes near the wedge supports and the IPC was not applied. The remaining indication was a hot leg indication above the 3.0 volt limit at 3.17 volt. There was one cold leg indication greater than 1.0 volt, but the voltage was less than the upper repair limit of 1.99 volt, and an RPC probe did not confirm the indication. Thus, ComEd returned the tube to service.

The staff concludes the licensee's bobbin and RPC probe inspections were consistent with the requirements in References 2 and 3 and thus are acceptable.

### 3.0 Comparison Between Actual and Predicted Conditional Probability of Burst and Total Leak Rate Under Postulated MSLB Conditions

The staff evaluated the ability of the predictive methodology discussed in References 2 and 3 to provide a conservative projection of the number and distribution of indications at the next EOC such that the estimated conditional probability of burst and total leak rate under postulated main steam line break (MSLB) conditions at the next EOC are conservative.

#### 3.1 Projected and Actual EOC-5B Voltage Distributions

In Reference 1, ComEd compared the actual EOC-5B bobbin voltage distributions with the corresponding predictions performed at the EOC-5A. (There was a midcycle inspection in February 1995. The first half of cycle 5 is referred to as cycle 5A and the second half is referred to as cycle 5B.) The methodology under predicted the number of indications lower than 0.7 volt and over predicted the number of indications greater than 0.7 volt. Since the larger voltages dominate the leak rate and burst integrity scenarios, this result is conservative. In general, the distribution shapes of the predicted versus actual results for the EOC-5B are similar (e.g., similar voltage peaks). Several voltages larger than 3.0 volt were predicted, but only one actual indication of 3.17 volt was reported.



### 3.2 Conditional Probability of Burst and Total Leak Rate Under Postulated MSLB Conditions

ComEd calculated the conditional probability of burst and the total leak rate under postulated MSLB conditions using the actual EOC-5B bobbin voltage distribution and then compared these values to those predicted at the EOC-5A using the predicted EOC-5B bobbin voltage distribution. The limiting conditional tube burst probability for one tube was  $6.49 \times 10^{-4}$ , compared with a predicted value of  $4.94 \times 10^{-3}$ . The limiting MSLB leak rate was 0.07 gpm, compared with a predicted value of 0.48 gpm. The comparison between values obtained using the actual voltage distributions compared with the values obtained using the predicted voltage distributions indicate the licensee used an appropriately conservative methodology.

### 4.0 Tube Integrity Evaluations

#### 4.1 Projected EOC-6 Voltage Distribution

ComEd projected the EOC-6 voltage distribution in accordance with GL 95-05 (Reference 3). For the EOC projections, GL 95-05 requires the use of the most limiting voltage growth rates observed during the last one or two inspection cycles. The licensee used the cycle 5A SG "A" distribution, which had the highest average growth and included the largest growth for SG "C," which had the highest growth increment of 5.7 volt. The EOC-5A hybrid growth distribution was used at the EOC-5A to predict EOC-5B indications and found to be conservative, as discussed in the preceding paragraph. The staff considers the ComEd approach to projecting the EOC-6 voltage distribution to be within the guidelines of GL 95-05 and thus acceptable.

#### 4.2 Database

ComEd used an updated version of the database described in Westinghouse Report SG-95-01-003, "Byron Unit-1 End-of-Cycle 6 Interim Plugging Criteria Report," Westinghouse Nuclear Service Division, June 1995. The licensee indicated the updated database is in compliance with NRC guidelines for application of leak rate versus voltage correlations and for removal of data outliers in the 3/4-inch tubing burst and leak rate correlations. The staff did not review the database as part of this evaluation.

#### 4.3 Conditional Probability of Burst

The conditional probability of burst refers to the probability that the burst pressures associated with one or more indications in the faulted SG will be less than the maximum pressure differential associated with a postulated MSLB assumed to occur at EOC. The staff considers an acceptable level of structural margin consistent with the applicable

General Design Criteria (GDC) of 10 CFR Part 50, Appendix A to be met with a conditional burst probability of less than  $1 \times 10^{-2}$ . The licensee performed this assessment using methodology previously approved by the NRC staff in Reference 2. The staff did not run confirmatory calculations as part of this review. Because the TSPs are locked in place on the hot leg side, the burst probability for those tubes is negligible. The number and size of cold leg indications projected to be in service at the EOC-6 are few and small, resulting in a limiting burst probability of  $6.81 \times 10^{-6}$ , far below the threshold value of  $1 \times 10^{-2}$ .

#### 4.4 Projected MSLB Leak Rate

The projected MSLB leak rate is calculated to ensure leakage from indications under worst case MSLB conditions will not result in offsite and control room dose releases that exceed the guidelines of 10 CFR part 100 and GDC 19. ComEd performed this assessment using methodology previously approved by the NRC staff in Reference 2. The staff did not run confirmatory calculations as part of this review. The limiting MSLB leak rate for projected indications at the EOC-6 is 6.99 gpm. This value is lower than the allowable leakage limit of 26.8 gpm.

#### 5.0 Tube Pull Results

ComEd did not pull any tubes during the EOC-5B outage. In 1994, the licensee removed four tubes from Braidwood-1 that included several TSP intersections. The metallurgical evaluation of the tubes supported the applicability of the voltage-based repair criteria to the SG tubes at Braidwood-1. A minimum of one additional tube with a minimum of two TSP intersections will be removed during the EOC-6 Braidwood-1 refueling outage (spring 1997). This schedule meets the requirements of GL 95-05 (Reference 3) and thus is acceptable to the staff.

#### References

1. "Braidwood Unit-1 Cycle 6 Interim Plugging Criteria 90 Day Report," Westinghouse Electric Corporation, NSD-SGD-1204, SG-96-02-002, February 1996.
2. Letter from M.D. Lynch (NRC) to D.L. Farrar (ComEd), "Issuance of Amendments," dated November 9, 1995.
3. Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," August 3, 1995.