50-456/457



# UNITED STATES NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C. 20555-0001

September 3, 1998

Mr. Oliver D. Kingsley, President Nuclear Generation Group Commonwealth Edison Company Executive T. wers West III 1400 Opus Place, Suite 500 Downers Grove, IL 60515

SUBJECT: REVIEW OF BRAIDWOOD, UNIT 1, STEAM GENERATOR 90-DAY REPORT (TAC NO. M99710)

Dear Mr. Kingsley:

By letter dated August 14, 1997, as supplemented by letters dated October 15, 1997, and January 14, 1998, the Commonwealth Edison Company (ComEd, the licensee) submitted its steam generator (SG) 90-day report, "Braidwood Unit-1 Cycle 7 Interim Plugging Criteria Report." The report summarized the licensee's assessment of the eddy current inspection results with respect to the guidance established for voltage-based tube repair criteria applied to indications located at the tube support plate (TSP) intersections and attributed to outside diameter stress corrosion cracking (ODSCC). During the refueling outage at the end-of-cycle 5 (EOC-5), ComEd implemented 1.0 volt Interim Plugging Criteria (IPC) to be applied to ODSCC at the TSP intersections on the cold leg side of the SGs and 3.0 volt IPC to be applied to ODSCC at the TSP intersections on the hot leg side of the SGs, with certain exceptions. The higher voltage repair limit is based on stabilization of the TSPs by expansion of selected tubes at the support plate intersections so that the TSPs could be credited as staying in place under postulated main steamline break (MSLB) conditions.

In the 90-day report, ComEd compared the predicted EOC-6 voltage distribution of ODSCC indications that was made at the EOC-5 with the actual EOC-6 voltage distribution of ODSCC indications. The licensee found the predicted voltage distribution was significantly nonconservative with respect to the actual voltage distribution. The nonconservative prediction of the EOC-6 voltage distribution resulted in a nonconservative calculation of the leak rate associated with an MSLB accident (e.g., a predicted value of 6.99 gallons per minute (gpm) versus an actual value of 11.5 gpm) although the actual value of 11.5 gpm was still within the site allowable leak rate limit of 19 gpm (room temperature conditions). ComEd found that the major contributor to the nonconservative prediction was the more frequent occurrence of large growth rates associated with larger indications (i.e., greater than 2.0 volts). Because the predictive methodology assumed a voltage-independent growth distribution, the apparent voltage-dependent behavior of ODSCC indications at Braidwood, Unit 1, was not accounted for and led to the nonconservative prediction of the EOC-6 conditions.

ComEd addressed this issue by revising the predictive methodology to account for voltagedependent growth rates. The licensee applied the revised methodology to predict the EOC-7 conditions. The staff reviewed the revised methodology and requested additional information from the licensee on September 19, 1997. The licensee responded in letters dated October 15, 1997, and January 14, 1998. The staff reviewed the licensee's response and concluded that the

9809080113 980903 PDR ADOCK 05000456 P PDR O. Kingsley

. .

- 2 -

revised methodology will provide a conservative prediction of the EOC-7 voltage distribution at Braidwood, Unit 1.

The nonconservative prediction of the EOC-6 voltage distribution did not affect the conditional probability of burst because the hot leg tubes, which make up the vast majority of the ODSCC indication population, are restricted from bursting by the locked TSPs and, thus, only cold leg indications contribute to the conditional probability of burst. The number and size of cold leg indications predicted to be in service at the EOC-7 are few and small, resulting in a limiting burst probability of 8 x 10<sup>-4</sup>, far below the threshold value of 1 x 10<sup>-2</sup>.

Using a bounding voltage binning strategy associated with the revised leak rate methodology, ComEd predicted a primary-to-secondary leak rate of 122 gpm at the EOC-7. The staff considers that estimate to be conservative. To ensure that 10 CFR Part 100 limits for offsite doses, or some fraction thereof, and General Design Criteria 19 for control room operator doses are met, the licensee placed administrative controls on the reactor coolant system dose equivalent iodine (DEI) level to maintain the steady state value of 0.05 microcuries/gram. On January 14, 1998, ComEd submitted a license amendment request to formally update the technical specifications at Braidwood, Unit 1, to reflect the reduced DEI level. This proposal would increase the allowable MSLB leak rate at Braidwood, Unit 1, to 132.8 gpm, encompassing the licensee's prediction of 122 gpm for EOC-7. The amendment is currently under staff review.

ComEd's estimate of 122 gpm leakage during an MSLB, while conservative, is a significant increase over the value previously accepted for Braidwood. The staff notes that steam generator tubes that are predicted to leak significantly during an MSLB may also leak and provide a containment bypass during other events that are not specifically analyzed as part of the plant's licensing basis (e.g., core damage accidents with high primary pressure, including station blackout (SBO) sequences leading to core melt and high primary system temperature and pressure while the secondary side is depressurized). The offsite doses for such scenarios are not effectively mitigated by reducing the DEI, as proposed in the January 14, 1998, submittal. For this reason, significant steam generator tube leakage could have risk implications for the health and safety of the public. With regard to risk, the staff considered the conservatism in ComEd's leakage predictions and the limited duration that this condition will exist (duration of Unit 1 Cycle 7). Based on this short time interval, coupled with the conservatism of the leakage calculations performed, the staff concludes the risk implications are acceptable.

The staff's review of the 90-day report is enclosed.

Sincerely,

Stewart N. Bailey, Project Manager Project Directorate III-2 Division of Reactor Projects - III/IV Office of Nuclear Reactor Regulation

Docket Nos. STN 50-456, STN 50-457 Enclosure: As stated

cc w/encl: See next page

. .

. .

revised methodology will provide a conservative prediction of the EOC-7 voltage distribution at Braidwood, Unit 1.

The nonconservative prediction of the  $\exists$ OC-6 voltage distribution did not affect the conditional probability of burst because the hot leg tubes, which make up the vast majority of the ODSCC indication population, are restricted from bursting by the locked TSPs and, thus, only cold leg indications contribute to the conditional probability of burst. The number and size of cold leg indications predicted to be in service at the EOC-7 are few and small, resulting in a limiting burst probability of 8 x 10<sup>-4</sup>, far below the threshold value of 1 x 10<sup>-2</sup>.

Using a bounding voltage binning strategy associated with the revised leak rate methodology, ComEd predicted a primary-to-secondary leak rate of 122 gpm at the EOC-7. The staff considers that estimate to be conservative. To ensure that 10 CFR Part 100 limits for offsite doses, or some fraction thereof, and General Design Criteria 19 for control room operator doses are met, the licensee placed administrative controls on the reactor coolant system dose equivalent iodine (DEI) level to maintain the steady state value of 0.05 microcuries/gram. On January 14, 1998, ComEd submitted a license amendment request to formally update the technical specifications at Braidwood, Unit 1, to reflect the reduced DEI level. This proposal would increase the allowable MSLB leak rate at Braidwood. Unit 1, to 132.8 gpm, encompassing the licensee's prediction of 122 gpm for EOC-7. The amendment is currently under staff review.

ComEd's estimate of 122 gpm leakage during an MSLB, while conservative, is a significant increase over the value previously accepted for Braidwood. The staff notes that steam generator tubes that are predicted to leak significantly during an MSLB may also leak and provide a containment bypass during other events that are not specifically analyzed as part of the plant's licensing basis (e.g., core damage accidents with high primary pressure, including station blackout (SBO) sequences leading to core melt and high primary system temperature and pressure while the secondary side is depressurized). The offsite doses for such scenarios are not effectively mitigated by reducing the DEI, as proposed in the January 14, 1998, submittal. For this reason, significant steam generator tube leakage could have risk implications for the health and safety of the public. With regard to risk, the staff considered the conservatism in ComEd's leakage predictions and the limited duration that this condition will exist (duration of Unit 1 Cycle 7). Based on this short time interval, coupled with the conservatism of the leakage calculations performed, the staff concludes the risk implications are acceptable.

The staff's review of the 90-day report is enclosed.

Sincerely, ORIG. SIGNED BY Stewart N. Bailey, Project Manager Project Directorate III-2 Division of Reactor Projects - III/IV Office of Nuclear Reactor Regulation

Docket Nos. STN 50-456, STN 50-457

Enclosure: As stated

cc w/encl: See next page DOCUMENT NAME: G:\CM\BRAID\BF'99710.LTR

To receive a copy of this document, indicate the box: "C" = Copy without enclosures "E" = Copy with enclosures "N" = No copy

OFFICE	PM:PDIII-2	6		R	D:PDIII-2	e	Distribut Docket File	ION:		Chicase
NAME	SBAILEY:sp		OMOORE		SRICHARDS SA		EAdensam	SRichards	ACRS OGC	
DATE	09/> /98		39/2 198		091 3 198		SBailey SLong GC		EMurphy VJordan, RIII	

OFFICIAL RECORD COPY

O. Kingsley Commonwealth Edison Company

CC:

. ....

Michael Miller, Esquire Sidley and Austin One First National Plaza Chicago, Illinois 60603

Regional Administrator U.S. NRC, Region III 801 Warrenville Road Lisle, Illinois 60532-4351

Illinois Department of Nuclear Safety Office of Nuclear Facility Safety 1035 Outer Park Drive Springfield, Illinois 62704

Document Control Desk-Licensing Commonwealth Edison Company 1400 Opus Place, Suite 400 Downers Grove, Illinois 60515

Ms. C. Sue Hauser, Project Manager Westinghouse Electric Corporation Energy Systems Business Unit Post Office Box 355 Pittsburgh, Pennsylvania 15230

Joseph Gallo Gallo & Ross 1250 Eye St., N.W., Suite 302 Washington, DC 20005

Ms. Bridget Little Rorem Appleseed Coordinator 117 N. Linden Street Essex, Illinois 60935

Howard A. Learner Environmental Law and Policy Center of the Midwest 35 East Wacker Dr., Suite 1300 Chicago, Illinois 60601

U.S. Nuclear Regulatory Commission Braidwood Resident Inspectors Office RR 1, Box 79 Braceville, Illinois 60407 Braidwood Station Units 1 and 2

Ms. Lorraine Creek RR 1, Box 182 Manteno, Illinois 60950

Mr. Ron Stephens Illinois Emergency Services & Disaster Agency 110 E. Adams Street Springfield, Illinois 62706

Chairman Will County Board of Supervisors Will County Board Courthouse Joliet, Illinois 60434

Attorney General 500 S. Second Street Springfield, Illinois 62701

George L. Edgar Morgan, Lewis and Bochius 1800 M Street, N.W. Washington, DC 20036

Commonwealth Edison Company Braidwood Station Manager RR 1, Box 84 Braceville, Illinois 60407

Commonwealth Edison Company Site Vice President - Braidwood RR 1, Box 84 Braceville, IL 60407

Mr.David Helwig Senior Vice President Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 900 Downers Grove, IL 60515

Mr. Gene H. Stanley PWR's Vice President Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 900 Downers Grove, IL 60515 O. Kingsley Commonwealth Edison Company

. ...

-2-

Commonwealth Edison Company Reg. Assurance Supervisor - Braidwood RR 1, Box 79 Braceville, Illinois 60407

Mr. Steve Perry BWR's Vice President Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 900 Downers Grove, IL 60515

Mr. Dennis Farrar Regulatory Services Manager Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 500 Downers Grove, IL 60515

Ms. Irene Johnson, Licensing Director Nuclear Regulatory Services Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 500 Downers Grove, IL 60515 Braidwood Station Units 1 and 2

Mr. Michael J. Wallace Senior Vice President Commonwealth Edison Company Executive Towers West III 1400 Opus Place, Suite 900 Downers Grove, IL 60515

### Review of the Braidwood, Unit 1, Steam Generator 90-Day Report

By letter dated August 14, 1997, as supplemented by letters dated October 15, 1997, and January 14, 1998, Commonwealth Edison Company (ComEd, the licensee) submitted its steam generator (SG) 90-day report, "Braidwood Unit-1 Cycle 7 Interim Plugging Criteria 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

4,

· · · ·

. . .

The Braidwood Nuclear Power Station, Unit 1 (Braidwood, Unit 1) has four Westinghouse model D4 SGs with 3/4-inch diameter tubes. During the refueling outage at the end-of-cycle 5 (EOC-5), ComEd implemented 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 3.0 volts IPC to be applied to ODSCC at the TSP intersections on the hot leg side of the SGs, with certain exceptions. The higher voltage repair limit is based on stabilization of the TSPs by expansion of selected tubes at the support plate intersections so that the TSPs could be credited as staying in place under postulated main steamline break (MSLB) conditions. References 2 and 3 describe the 1.0 volt and 3.0 volts IPC methodologies in detail.

The licensee used a lower repair limit of 1.0 volt and determined an upper voltage repair limit of 2.04 volts to disposition ODSCC at TSP intersections on the cold leg side. Indications with bobbin coil voltages less than or equal to 1.0 volt were left in service, indications with bobbin coil voltages greater than 2.04 volts were removed from service, and indications with bobbin coil voltages between 1.0 and 2.04 volts were removed from service if confirmed with a rotating probe. ComEd used a repair limit of 3.0 volts to disposition ODSCC at TSP intersections on the hot leg side. Indications with bobbin coil voltages greater than 3.0 volts were left in service while indications with bobbin coil voltages greater than 3.0 volts were removed from service.

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

ComEd inspected 100 percent of its SG tube's full length using a 0.610-inch diameter bobbin coil at all intersections to which the IPC was applied. For the hot leg tubes where the 3.0 volts IPC was applied, the licensee used a rotating probe to inspect 20 percent of bobbin voltages between 1.0 and 3.0 volts and all bobbin voltages greater than 3.0 volts. For tubes where the 1.0 volt IPC is applied, the licensee used the rotating probe to inspect 100 percent of bobbin voltages greater than 1.0 volts.

ComEd also used a rotating probe to inspect all intersections with dent signals greater than 5.0 volts, a 20 percent sample of intersections with bobbin dent voltages between 2.5 and 5.0 volts, and all intersections with large mixed residuals. The licensee detected a single circumferential indication extending 123° in a large (approximately 24 volts) dent at the fifth TSP.

ComEd reported a total of 6,784 ODSCC indications at TSP intersections and returned 6,506 indications to service at Braidwood, Unit 1. Of the 278 indications removed from service, 169 indications were in tubes plugged for degradation mechanisms other than ODSCC at the TSPs

ENCLOSURE

or were in tubes near the wedge supports where IPC was not applied. The remaining 109 indications were above the IPC repair limits: 107 were in hot leg tubes and sized greater than 3.0 volts; the remaining 2 indications were in cold leg tubes and sized between 1.0 and 2.04 volts and were confirmed with a rotating probe.

The staff concludes the licensee's eddy current inspections and plugging criteria were consistent with the guidance in References 2 and 3 and thus are acceptable.

## 3.0 Probe Wear

.

Licensees monitor the eddy current bobbin probe wear. If the probe is found to be outside of its ±15 percent wear specification, licensees reinspect all tubes inspected since the last successful calibration with a new, calibrated probe. Reference 3 permitted alternatives to this approach subject to NRC approval.

The Nuclear Energy Institute (NEI) submitted an alternative probe wear approach to the NRC for review. The industry approach is such that if the amplitude from the probe wear standard prior to probe replacement exceeds the ±15 percent limit, all tubes with voltage responses measured at 75 percent or greater of the lower voltage repair limit must be reinspected with a bobbin probe satisfying the ±15 percent wear standard criterion. The voltages from the reinspection are used as the basis for tube repair. The NRC staff completed a review of the proposed alternative method and concluded the approach is acceptable as documented in Reference 4.

At the EOC-6, ComEd implemented the alternate probe wear criteria at Braidwood, Unit 1. All tubes with indications greater than 75 percent of the lower voltage repair limit (1.0 volt) were reinspected with a probe which satisfied the probe wear criterion including hot leg indications to which a 3.0 volts repair criterion was applied. In its 90-day report, the licensee evaluated the alternative approach and concluded it was adequate. Voltages measured with a worn probe and a new probe at the same location were compared. The new probe did not detect any new large indications; thus, worn probes did not miss significant indications. Several indications around the 1.0 to 1.5 volts range had worn probe voltages less than the new probe and, thus, were not pluggable indications. Overall, the licensee concluded that the criteria to retest tubes with worn probe voltages above 75 percent of the repair limit are adequate.

# 4.0 <u>Comparison Between Actual and Predicted EOC-6 Conditional Probability of Burst and</u> <u>Total Leak Rate Under Postulated MSLB Conditions</u>

The staff evaluated the licensee's ability to conservatively predict the number and distribution of indications such that the estimated conditional probability of burst and total leak rates under postulated MSLB conditions were also conservatively predicted.

In Reference 1, ComEd compared the actual EOC-6 bobbin voltage distribution with the corresponding predictions for the EOC-6 voltage distribution performed at the EOC-5. The licensee found the predictions, in general, underestimated the actual EOC-6 conditions; particularly the distribution of indications greater than 3.0 volts. ComEd identified one reason for the under estimation: an increased growth rate during cycle 6 as compared to the previous two cycles. However, when the licensee recalculated the EOC-6 voltage distribution using the actual

cycle ô growth rate, ComEd still under estimated the EOC-6 voltage distribution in that the number and size of the largest (i.e., greater than 3.0 volts) indications were not predicted. The licensee concluded from this that there was a problem with the predictive methodology itself, at least as it applied to Braidwood, Unit 1.

Through its root-cause evaluation, ComEd found that although the relative amount of growth over a cycle of operation appeared to be fairly independent of the beginning-of-cycle (BOC) voltage, the <u>frequency</u> of the occurrence of high growth rates increased as the BOC voltage increased. Because the licensee applied a single growth rate distribution to all BOC indications (i.e., ComEd assumed growth to be independent of BOC voltage), the probability of the occurrence of large growth rates was diluted by the large number of indications at low voltages. Thus, the licensee's predictive methodology resulted in a nonconservative prediction of the EOC conditions at Braidwood, Unit 1.

The nonconservative prediction of the EOC-6 voltage distribution resulted in ComEd's under predicting the total leak rate under postulated MSLB conditions. The predicted EOC-6 limiting MSLB leak rate was 6.99 gallons per minute (gpm). The EOC-6 limiting MSLB leak rate based on actual EOC-6 conditions was 11.5 gpm. ComEd's site allowable leak rate limit is 19.0 gpm (room temperature conditions). Thus, the under prediction did not result in the licensee exceeding it's site allowable leak rate limits.

The nonconservative prediction of the EOC-6 voltage distribution did not affect the conditional probability of burst because the hot leg tubes, which make up the vast majority of the ODSCC indication population, are restricted from bursting by the locked TSPs and, thus, only cold leg indications contribute to burst. The voltage distribution of the cold leg indications was conservatively predicted.

### 5.0 Tube Integrity Evaluations for EOC-7

For its predictions of the EOC-7 voltage distribution, ComEd modified the growth rate distribution applied to the BOC-7 indications to account for the apparent voltage-dependency discussed above. First, the licensee formed a "hybrid" growth distribution that contains the growth rate distribution from the limiting SG, including the three largest growth values found in any of the four SGs. Second, ComEd plotted voltage growth over cycle 6 as a function of the BOC-6 voltage for the hybrid distribution and used this plot to divide the growth distribution into voltage bins that reflect the differences in growth rate. Third, ComEd applied the voltage growth distribution for each voltage bin to the BOC-7 indications with corresponding voltages. In this way, the licensee accounted for the apparent increase in the frequency of large growth rates for larger BOC-7 indications as seen in the past operating cycle. ComEd benchmarked the revised methodology by recalculating the EOC-6 predictions and found the revised methodology conservatively predicted the actual EOC-6 voltage distribution.

The staff challenged the licensee's assumption that the growth rates of larger BOC-7 indications would continue to behave as they did in cycle 6. ComEd's experience with growth rate behavior of indications greater than 2.0 volts was limited and there existed the possibility that the voltage dependent growth described above would become more exaggerated over time. The licensee responded to the issue by letters dated October 15, 1997, and January 14, 1998 (References 5 and 6). In the letter dated January 14, 1998, ComEd provided substantial evidence from

domestic and foreign plants domonstrating that the growth rate of indications in the 2.0 to 3.0 volts range is predictable and that the revised methodology is conservative. In addition, the licensee applied a bounding voltage binning strategy to provide a conservative prediction of the EOC-7 voltage distribution. The staff concludes that the revised methodology, a simple variation of the standard methodology described in References 2 and 3, is reasonable and effective, in that it will provide a conservative prediction of the EOC-7 voltage distribution at Braidwood, Unit 1.

The predicted MSLB leak rate is calculated to ensure that leakage from tube 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 General Design Criterion (GDC) 19. ComEd performed this assessment using a bounding voltage binning strategy associated with the revised leak rate methodology and predicted a primary-to-secondary leak rate of 122 gpm at the EOC-7. The licensee placed administrative controls on the reactor coolant system dose equivalent iodine (DEI) level to maintain the steady state value at 0.05 microcuries/gram. On January 14, 1998, ComEd submitted a license amendment request to formally update the technical specifications at Braidwood, Unit 1, to reflect the reduced DEI levels. This proposal would increase the allowable MSLB leak rate at Braidwood, Unit 1, to 132.8 gpm, encompassing the licensee's prediction of 122 gpm for EOC-7. The license amendment is currently under staff review.

The licensee's proposal is based on the premise that MSLB is the most limiting design basis accident (DBA) for offsite and control room doses, by virtue of the fact that MSLB involves the highest differential pressures and, thus, the highest leak rates and associated radiological consequences for a given population of flaws. A scoping assessment performed for Farley supports the reasonableness of this assumption based on DEI levels at Standard Technical Specification values (Reference 7). However, the proposed strategy for Braidwood, Unit 1, to accommodate additional accident leakage through a corresponding reduction in the DEI level creates the possibility that locked rotor or rod ejection accidents may be more limiting than MSLB since, if fuel failures occur, the dose consequences from these events will be little affected by the reduction in DEI. Accordingly, the staff issued a Request for Additional Information (RAI) requesting that ComEd provide an assessment to confirm that MSLB is the bounding DBA for offsite and control room doses if the proposed license amendment is approved. The RAI requested that the assessment consider: (1) the increase in leak rate that occurs during a locked rotor or rod ejection accident, (2) assumed fuel failure for these accidents, and (3) potential for uncovery of the leaking defect locations. The MSLB leakage calculations (discussed above) conservatively take no credit for any constraint against leakage provided by the TSPs and the TSP crevice deposits due to the potential for TSP displacement under blowdown loadings associated with the accident which would expose the cracks. For the locked rotor and rod ejection accidents, no TSP displacement would be expected and, thus, the cracks would remain confined within the thickness of the TSP. For this reason, the RAI suggested that as part of its assessment ComEd may wish to evaluate the constraint against leakage provided by the TSP and crevice deposits under the pressure/temperature conditions associated with these accidents. including any potential for flashing sleam to cut through the crevice deposits. The RAI stated that such an evaluation should provide supporting data, analyses, and assumptions. ComEd responded to the RAI by letter dated July 17, 1998, stating, in part, that the MSLB was bounding because there are no fuel failures associated with the above accidents for Braidwood, Unit 1, cycle 7.

. .

Since previously approved license amendments among units with the voltage-based alternate repair criteria involved allowable MSLB leak rates of only 25.3 gpm or less, the staff took the additional step of considering the risk implications of the proposed amendment. In those previous cases, it was determined by the staff in approving these limits that the risk implications for the spectrum of accident scenarios, including severe accidents, were negligible. That judgement was based on qualitative considerations. The MSLB leakage calculations conservatively take no credit for any constraint against leakage provided by the TSPs and the TSP crevice deposits due to the potential for TSP displacement under blowdown loadings associated with the accident which would expose the cracks. These TSP displacements are unique to the MSLB accident. For other accidents, no TSP displacement would be expected and, thus, the cracks would remain confined within the thickness of the TSP where the leakage would be expected to be significantly constrained compared to what would exist for exposed cracks. Based on this, it was assumed that the leakage, and any potential containment bypass effects, would be minimal.

The proposed increase in the allowable MSLB leak rate prompted the staff to consider the above assumptions as they relate to containment bypass. There are significant conservatisms in the model used to estimate leakage, but there are also significant uncertainties pertaining to the constraint against leakage provided by the TSPs and associated crevice deposits. The staff has considered the following:

- ComEd employed a very conservative voltage binning strategy, as discussed earlier, to support its estimate of the potential MSLB leak rate at EOC-7. The licensee reviewed a substantial amount of foreign and domestic plant data and performed several benchmarking studies on that data. ComEd's submittal provided strong support that a realistic and conservative estimation of the accident leak rate for the EOC-7 conditions would be approximately 60 gpm (assumes 6.1 gpm for each indication restrained from burst).
- 2. Except as noted for indications restrained from burst (IRBs), the empirical model used to calculate MSLB leakage is intended to produce a 95% upper quantile estimate evaluated at the 95% confidence level based on the available field and laboratory data for freespan cracks. Best estimate predictions for non-IRB defects are typically an order of magnitude lower. However, a significant fraction of the estimated total leak rate at Braidwood, Unit 1, is contributed by IRBs. The MSLB leakage model assumes 6.1 gpm leakage for each IRB, which bounds available laboratory specimen leakage data. A recent test of a pulled tube specimen under IRB conditions produced a leak rate of 0.9 gpm, corroborating the conservatism of the assumed IRB leak rates.
- 3. The support plates and associated crevice deposits have proven effective in minimizing the occurrence of operational leakage under normal operating pressures and temperatures in spite of the widespread presence of through-wall cracks at these intersections at a large number of plants. No instances of operational leakage leading to forced shutdowns due to ODSCC at the support plates have been reported in the U.S. The presence of such widespread through-wall cracks in the freespan would be expected to cause frequent forced shutdowns due to leakage.
- 4. French laboratory tests of tube to support plate intersections with included crevice deposits demonstrates a one to two order of magnitude reduction in leak rate associated with the

resistance of the crevice deposits. This test was performed under cold conditions with simulated MSLB differential pressure. The tube specimens each contained drilled through-wall holes. Thus, the test did not include the containing effect of the packed crevice deposits against crack opening displacement; which is thought to be an important effect and would further reduce leakage. However, similar tests under hot conditions have not been performed. Furthermore, any tendency for flashing steam or hot gases (under high temperature/high pressure severe accident conditions) to cut through the crevice deposits has not been evaluated.

A key uncertainty to be resolved is the leakage constraint provided by the support plates and associated crevice deposits, including the potential for flashing steam or hot gases (associated with high temperature/high pressure severe accident scenarios) to cut through the crevice deposits. However, the 122 gpm leakage prediction and the proposed license amendment for Braidwood will apply to cycle 7 operation only, since the SGs are scheduled for replacement at the conclusion of the cycle. Based on this short time interval coupled with the conservatism of the leakage calculations performed, the staff concludes the risk implications of the proposed license amendment is acceptable.

The conditional probability of burst refers to the probability that the burst pressures associated with one or more indications in the faulted SG at EOC will be less than the maximum pressure differential associated with a postulated MSLB. The staff considers an acceptable level of a structural margin consistent with the applicable GDC of 10 CFR Part 50, Appendix A, to be met with a conditional burst probability of less than 1 x  $10^{-2}$ . The licensee performed this assessment using methodology previously approved by the NRC staff in Reference 2. 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 predicted to be in service at the EOC-7 are few and small, resulting in a limiting burst probability of 8 x  $10^{-4}$ , far below the threshold value of 1 x  $10^{-2}$  and is acceptable.

### 6.0 Tube Pull Results

•••

ComEd removed two tubes from SG "A" during the EOC-6 refueling outage to examine eddy current indications located at the TSP intersections. Tube R28C24 had a 6.2 volt bobbin signal at the fifth TSP and a 0.68 volt bobbin signal at the third TSP. Tube R41C65 had an 8.93 volt bobbin signal at the fifth TSP and a 0.41 volt bobbin signal at the third TSP. All other TSP intersections had no detectable degradation. The metallurgical evaluation confirmed the nature of the eddy current indications to be axially-oriented ODSCC.

ComEd completed leak testing of the indications located at the fifth TSP of the above two tubes. Leakage through the indications under accident conditions was measured at 0.023 gallons/minute and 0.033 gallons/minute for tube R28C24 and tube R41C65, respectively.

The licensee performed additional leak rate tests to simulate leakage from an indication restrained from burst (IRB). After completing the standard leak testing described above, the indication at the fifth TSP in tube R28C24 was pressurized to 6670 psi inside a simulated TSP. (This pressure was calculated to be 670 psi greater than the nominal burst pressure based on eddy current voltage correlation and the measured material properties.) The indication was then

subjected to a series of pressures for two conditions: (1) with the indication offset with respect to the TSP simulant such that approximately 0.12 inches of the crack was outside the TSP simulant, and (2) with the entire indication covered by the TSP simulant. The licensee tested at 1300, 1800, 2300, 2560 and 2900 psi. Leakage increased with increasing pressure, with a maximum leak rate of approximately 1.31 gallons/minute at 2900 psi for the offset condition and 1.30 gallons/minute for the covered condition. These values are less than the 6 gallons/minute leak rate currently assumed for IRBs.

Following leak rate testing, ComEd completed burst testing of the indications located at the fifth TSP. The adjusted burst pressures for tube R28C24 and tube R41C65 were 5,624 psi and 4,937 psi, respectively. These burst pressure values are within Regulatory Guide 1.121 margins for Braidwood, Unit 1.

Following burst testing, ComEd measured the tensile force required to pull apart the indications located at the fifth TSP. The separation loads were 7,700 pounds for Tube R28C24 and 7,400 pounds for Tube R41C65. The results of the axial tensile rupture tests were consistent with past test results and continue to support a very low conditional probability of tube failure due to axial separation.

ComEd evaluated the leak and burst test results discussed above and found the inclusion of the additional data will not impart significant changes in the IPC database; i.e., the intercept, slope, and various other regression parameters are only modestly changed. For example, the net effect on the MSLB structural limit by including the new data is a small increase in voltage from 4.73 to 4.79 volts. The staff expects the Braidwood, Unit 1, data will be incorporated in the next update of the database. In summary, the results of the Braidwood, Unit 1, tube pulls appear to be consistent with the Reference 3 guidance. The metallurgical evaluation of the tubes supported the continued applicability of the voltage-based repair criteria to the SG tubes at Braidwood, Unit 1.

#### References

. . . . .

- "Braidwood Unit-1 Cycle 7 Interim Plugging Criteria Report," Westinghouse Electric Corporation, SG-97-08-002, August 1997.
- Letter from M. D. Lynch (NRC) to I. M. Johnson (ComEd), "Issuance of Amendments," dated May 14, 1997.
- Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," August 3, 1995.
- 4. Letter from B. W. Sheron (NRC) to A. Marion (NEI) dated February 9, 1996.
- Letter from J. B. Hosmer (ComEd) to NRC Document Control Desk, "Response to Request for Additional Information Regarding Proposed Technical Specification for the Reduction in Dose Equivalent Iodine," dated October 15, 1997.
- Letter from H. G. Stanley (ComEd) to NRC Document Control Desk, "Braidwood Unit 1 3 Volt IPC, Full Cycle Operation Technical Basis, Supplement to Braidwood Unit 1 Cycle 7 Interim Plugging Criteria Report," dated January 14, 1998.
- Letter from J. I. Zimmerman (NRC) to D. N. Morei (Southern Nuclear Operating Company), "Issuance of Amendments," dated April 29, 1998.