UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 95 TO FACILITY OPERATING LICENSE NO. NPF-72

AND AMENDMENT NO. 95 TO FACILITY OPERATING LICENSE NO. NPF-77

COMMONWEALTH EDISON COMPANY

BRAIDWOOD STATION, UNIT NOS. 1 AND 2

DOCKET NOS. STN 50-456 AND STN 50-457

1.0 INTRODUCTION

By letter dated January 14, 1998, as supplemented by letter dated July 17, 1998, Commonwealth Edison Company (ComEd, the licensee) requested a change to the Technical Specification (TS) limit on Reactor Coolant System (RCS) Dose-Equivalent Iodine-131 (DEI) for Braidwood Station, Unit 1. The change would reduce the DEI from the current limit of 0.35 microcuries/gram (µCi/gm) to 0.05 µCi/gm for the remainder of Cycle 7. The July 17, 1998, submittal provided additional clarifying information that did not change the initial proposed no significant hazards consideration determination.

Braidwood, Unit 1, is currently operating under an operability assessment and has established an administrative control which limits DEI to 0.05 µCi/gm. The change to the DEI limit is necessary due a higher prediction of the primary-to-secondary leakage in the affected steam generator (SG) during a main steamline break (MSLB) accident. The leakage is associated with the interim plugging criteria (IPC) used for the Braidwood, Unit 1, SG tubes that were approved by the NRC by letter dated May 14, 1997 (amendment number 82). Consistent with the guidance in NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," ComEd evaluated a MSLB and reduced the DEI in order to ensure that (1) the 10 CFR Part 100 limits, or some fraction thereof, are met for offsite doses, and (2) 10 CFR Part 50, Appendix A, General Design Criterion 19 is met for control room doses. This issue is only applicable until the end of Cycle 7, at which time the SGs will be replaced.

During the spring 1997 refueling outage at the end-of-cycle (EOC) 6, ComEd compared the actual EOC-6 voltage distribution of indications attributed to outside-diameter stress corrosion cracking (ODSCC) with the predictions that were made at the beginning of the cycle. The licensee found the predicted voltage distribution was significantly nonconservative with respect to the actual voltage distribution. ComEd found that the major contributor to the nonconservative prediction was the more frequent occurrence of large growth rates associated with larger ODSCC 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. The nonconservative prediction of the EOC-6 voltage distribution resulted in a nonconservative calculation of the leak rate associated with a MSLB.

ComEd addressed this issue by revising the predictive methodology to account for voltage-dependent growth rates. ComEd applied the revised methodology to predict the EOC-7 conditions. The staff reviewed the revised methodology and questioned the adequacy of the binning strategy and the benchmarking. ComEd performed sensitivity studies on the binning and conducted additional benchmarking and used this information to develop a conservative upper bound to the leakage. This information is contained in a supplement to the "Braidwood Unit 1 Cycle 7 Interim Plugging Criteria Report" (also called the 90-day report), submitted on January 14, 1998. Using a bounding voltage binning strategy, ComEd predicted a primary-to-secondary leak rate of 122 gpm at the EOC-7. Based on this leak rate, ComEd determined that the DEI should be lowered to 0.05 μCi/gm.

The staff reviewed the 90-day report and concluded that the revised methodology provided a conservative prediction of the EOC-7 voltage distribution and leak rate. The staff's review of the 90-day report is documented in a letter to ComEd dated September 3, 1998.

2.0 EVALUATION

ComEd proposed to reduce the DEI limits from 0.35 to 0.05 μCi/gm for the 48 hour limit, and from 21 to 3 μCi/gm for the instantaneous limit, for the remainder of Braidwood, Unit 1, Cycle 7. These limits are based on increasing the total MSLB leak rate to 132.8 gpm, which encompasses ComEd's prediction of 122 gpm in the affected SG for EOC-7. Leakage in the unaffected SGs remains at 150 gpd, the TS limit for normal operation.

The licensee performed an assessment of the radiological dose consequences of a MSLB in support of its amendment request. Braidwood, Unit 1, is currently approved to operate based upon 26.8 gpm primary-to-secondary leakage with a DEI limit of 0.35 μCi/gm. The licensee found the dose consequences of increasing the total leakage to 132.8 gpm to be acceptable, with DEI reduced to 0.05 μCi/gm, based on the NRC acceptance criteria for doses at the Exclusion Area Boundary (EAB), the Low-Population Zone (LPZ), and the control room. ComEd provided additional information by letter dated July 17, 1998, to confirm that MSLB is the bounding design basis accident that is affected by accident-induced SG tube leakage.

Assessment of Higher Steam Generator Tube Leakage

As mentioned above, ComEd predicted 122 gpm primary-to-secondary leakage in the affected SG during a MSLB. This prediction was made for the purpose of the dose calculations that were performed in accordance with the guidance in Generic Letter 95-05. The staff has reviewed this prediction and concludes that it is conservative and acceptable for that purpose.

Nevertheless, the staff considers a leakage value of 122 gpm to be high. The SG tubes serve as a containment barrier as well as the reactor coolant pressure boundary. Tubes which may leak at 122 gpm during a design basis MSLB may leak significantly and provide a containment bypass mechanism 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). Decreasing the allowable limit on DEI does not effectively mitigate the offsite dose from these events. For this reason, significant steam generator tube leakage could have risk implications for the health and safety of the public. In keeping with the Commission's policy for incorporating risk insights into the regulatory decision-making process, the staff considered the potential defense-in-depth and risk implications of the SG tube leakage predictions that support this license amendment.

The staff has considered the following:

1. ComEd employed a very conservative voltage binning strategy 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 those data. The 90 day report provided strong support that a realistic and conservative estimate of the accident leak rate for the EOC-7 conditions would be approximately 60 gpm (based on 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 an 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. Had these through wall cracks been located in the freespan, the cracks would be expected to cause frequent forced shutdowns due to leakage.

4. Laboratory tests of tube to support plate intersections with included crevice deposits, in France, 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.

The staff notes that operation in the above condition is limited until the end of the current operating cycle, since the SGs are scheduled to be replaced. Based on this short time interval coupled with the conservatisms of the leakage calculations, the staff concludes that the proposed license amendment is acceptable.

Evaluation of Reducing Reactor Coolant System Dose Equivalent ^{131}I Limits below 0.35 µCi/gm

Generic Letter 95-05 states that licensees who wish to take credit in the radiological dose calculation for reducing DEI below 0.35 µCi/gm should provide a justification that evaluates the release rate data described in a report by J.P. Adams and C.L. Atwood entitled, "The Iodine Spike Release Rate During a Steam Generator Tube Rupture" (Nuclear Technology, Volume 94, page 361 (1991)). The requested information was contained in ComEd's application.

In the evaluation, ComEd indicated that Braidwood Station has experienced six occasions where the iodine spiking factor was greater than 500, which is the value assumed by the licensee in its dose assessment. A spiking factor of 500 is recommended for use in analyzing the consequences of MSLB and Steam Generator Tube Rupture (SGTR) accidents and is discussed in Standard Review Plan (SRP) Sections 15.1.5 and 15.6.3 (NUREG 0800). Because spiking data have shown occasions where spikes greater than 500 have occurred for DEI lower than 0.3 µCi/gm, the licensee addressed the implications of lowering the primary coolant activity to a value of 0.05 µCi/gm.

The licensee evaluated the Braidwood data against the SRP methodology. For a steady-state reactor coolant activity level of 1.0 µCi/gm, the licensee calculated a pre-trip release rate of iodine from the fuel of 27.5 curie/hour (Ci/hr). Based upon the SRP spiking factor of 500, the licensee determined the maximum release rate to be 13,733 Ci/hr. The highest release rate from the Braidwood trip data was 1,335 Ci/hr. The licensee stated that previously the doses were determined to be acceptable at 1.0 µCi/gm. A reduction in reactor coolant activity level to 0.05 µCi/gm would offset a 20 fold increase in primary to secondary leak rate and would result in a release rate of 686.7 Ci/hr. Two of the Braidwood data points showed release rates exceeding 686.7 Ci/hr, while 15 of the data points in an article in Nuclear Technology by Adams and Atwood in June 1991 exceeded this value. Of the 17 data points, only two had a pre-trip reactor coolant activity level below 0.05 µCi/gm.

When the Braidwood data were combined with the data by Adams and Atwood, the licensee concluded that the Braidwood data would not change the conclusions which were reached by Adams and Atwood. Although the Braidwood data included spiking factors greater than 500 when DEI was less than 0.3 µCi/gm, none of the data approached the proposed TS value of 0.05 µCi/gm. The licensee reviewed the combined Adams and Atwood data and Braidwood data in the range of 0.01 µCi/gm through 0.1 µCi/gm. In this range of reactor coolant activity level, the licensee determined that 76 percent of the data points had spiking factors which were below 500. The Adams and Atwood data showed that the highest spiking factor at the Pre-Trip activity of 0.05 µCi/gm was 773. The licensee indicated that the corresponding release rate of 368 Ci/hr at this value was less than the maximum calculated Braidwood release rate of 686.7 Ci/hr which was calculated for a primary coolant activity level of 0.05 µCi/gm and a spiking factor of 500.

The licensee also indicated that Adams and Atwood had derived a 95 percent/85 percent iodine release rate of 0.608 Ci/hr per megawatt electric (MWe). Application of this value at Braidwood would result in a calculated release rate of less than 714 Ci/hr. Of 17 reactor trips at Braidwood, two had exceeded 686.7 Ci/hr. Both occurred during cycles with fuel defects. Braidwood, Unit 1, is currently operating with no fuel defects. The licensee concluded the probability of iodine release rate exceeding 686.7 Ci/hr is small. The licensee further concluded that, due to the conservatisms in the dose analysis, there is a low probability of exceeding a small fraction of the 10 CFR Part 100 limits should a fuel release rate greater than 686.7 Ci/hr occur.

The licensee also utilized the results of the draft EPRI Report TR-103680, Rev. 1, November 1995, "Empirical Study of Iodine Spiking in PWR Power Plants," in its assessment of spiking factors for primary coolant at 0.05 µCi/gm. The EPRI report had spiking factors in the range of 45-150. This supports the conclusion that the NRC spiking factor of 500 is conservative.

The licensee used the EPRI empirical model to predict the rate of iodine release from the fuel rods in postulated MSLB/SGTR accident sequences. Since the RCS mass and the clean-up system constant for Braidwood are similar to that used in the EPRI model, the licensee used the SRP methodology with a DEI of 1.0 µCi/gm and a spiking value of 500. The resulting post-trip RCS activity 2 hours after the event is approximately 38 µCi/gm. At a DEI of 0.05 µCi/gm, it would require a spiking factor of nearly 10,000 to obtain a post-trip RCS activity near 38 µCi/gm. With a post-trip RCS activity of 38 µCi/gm, an increase in the allowable leak rate could impact the 10 CFR Part 100 limits. To accommodate an increase in the allowable leak rate by a factor of 20 (1.0 µCi/gm / 0.05 µCi/gm), the resultant activity would need to be below 1.9 µCi/gm. Although two of the seventeen post-trip data points from Braidwood exceeded 1.9 µCi/gm, both occurred during cycles with fuel defects. Braidwood, Unit 1, is currently operating with no fuel defects.

The staff has recently evaluated the issue of iodine spikes greater than 500 for primary coolant activity levels less than 1.0 µCi/gm. The staff examined the possibility of spiking factors increasing as a function of decreasing reactor coolant activity levels. One of the problems in addressing this issue is the lack of spiking data associated with MSLB events. All spiking data are associated with events typifying a SGTR. There is a certain amount of uncertainty when trying to project the magnitude of an iodine spike resulting from a MSLB using data which are more representative of a SGTR. One could estimate a spike from a MSLB to be within a factor of 10 of the spike from a SGTR based upon pressure drops and pressure drop rates of a MSLB to be within a factor of three of those of a SGTR. Adams has indicated that the spiking factor for a SGTR may be conservative by an order of magnitude. Given the order of magnitude conservatism in the SGTR spiking factor and estimating that the MSLB iodine spike is an order of magnitude higher than the SGTR spike, the staff determined that the two factors tend to offset each other.

The staff believes that the uncertainty associated with the iodine spiking factor was recognized in the development of SRPs 15.1.5 and 15.6.3 when the acceptance criterion for the accident-initiated spike case was established as a small fraction of 10 CFR Part 100. Establishing the acceptance criterion for this case at 10 percent of 10 CFR Part 100 limits allows a certain degree of error in the spiking assessment. If the dose consequences for the accident-initiated spike case were a small fraction (i.e., 10 percent) of 10 CFR Part 100, then a spiking factor of 5,000 (10 x spiking factor of 500) would need to occur before doses would exceed 10 CFR Part 100. The existing spiking data, even with consideration of an increase factor of 10 to account for a MSLB event, do not tend to support the suggestion that spiking factors in the 5,000 range are a likely occurrence. Therefore, the staff has concluded that the dose criteria are sufficient to address potential uncertainties in spiking factors associated with reactor coolant activity levels less than 1 µCi/gm.

The staff concludes that the use of a spiking factor of 500 is acceptable for analysis of this application.

Review of Radiological Analysis

The staff reviewed the licensee's calculations and performed confirmatory calculations to check the acceptability of the licensee's methodology and the resulting doses. The staff calculated the doses resulting from a MSLB accident using the methodology associated with SRP 15.1.5, Appendix A. The staff performed two separate assessments. One was based upon a pre-existing iodine spike, with an RCS activity of 3 μCi/g, and the other was based upon an accident initiated iodine spike. For the accident initiated spike case, the staff assumed that the DEI was 0.05 μCi/gm. The accident initiated an increase in the release rate of iodine from the fuel by a factor of 500 over the normal release rate that would maintain a DEI of 0.05 μCi/gm.

For these two cases, the staff calculated the thyroid doses for individuals located at the exclusion area boundary (EAB) and at the low-population zone (LPZ). The staff also calculated the thyroid dose to the control room operator. The parameters which were utilized in the staff's assessment are presented in Table 1 (attached). The staff used the lower range (nominal flow rate value less ten percent) of values for control room makeup and recirculation flow rates, as allowed by the TS. The EAB, LPZ, and control room doses calculated by the staff are presented in Table 2 (attached). The staff's calculations confirmed that the doses from a postulated MSLB meet the acceptance criteria and that the licensee's calculations are acceptable.

The results of both the licensee's and staff's calculations showed that the offsite doses met the guidelines of SRP 15.1.5, Appendix A (i.e., 10 CFR Part 100 limits, or a fraction thereof) and that the control room doses met the guidelines of SRP 6.4 (i.e., 10 CFR Part 50, Appendix A, General Design Criteria 19). On this basis, the staff finds the requested reduction in the allowable DEI from 0.35 to 0.05 μCi/gm, along with the increase in the allowable maximum primary to secondary leakage, to be acceptable.

3.0 SUMMARY

The staff reviewed the licensee's prediction of the primary-to-secondary leakage following a main steam line break accident, which was submitted in the 90 day report for the interim plugging criteria used at Braidwood Unit 1. The licensee predicted 122 gpm using a bounding binning strategy in their model of voltage-dependent growth rates for ODSCC indications at the tube support plates. The staff concludes this leakage estimate is bounding and conservative. However, the staff believes leakage at this level can contribute to the risk from events that are not specifically modeled as part of the plant's licensing basis (e.g. core damage accidents). The staff considered the risk implications and concluded that, based on the short time interval (e.g. limited to the duration of Braidwood Unit 1 cycle 7) coupled with the conservatism of the leakage calculations, the risk implications of the proposed license amendment are acceptable.

The staff performed a radiological dose assessment to determine the consequences of the increased primary-to-secondary leakage and reduced DEI. The staff calculated the potential consequences based upon two conditions: a pre-existing iodine spike and an accident initiated iodine spike. The evaluation assumed that the activity level of dose equivalent ^{131}I in the primary coolant was 0.05 μCi/gm for the accident-initiated spike and 3 μCi/gm for the pre-existing spike. The staff concludes that the proposed change meets the 10 CFR Part 100 limits for offsite doses and 10 CFR Part 50, Appendix A, General Design Criterion 19 for control room doses and is acceptable.

The staff is aware that when primary coolant activity levels of dose equivalent ^{131}I approach values of 0.1 μCi/gm or lower, data show that the probability of iodine spiking factors greater than 500 increases. The staff believes, however, that the probability of accident doses exceeding 10 CFR Part 100 limits as a result of limiting primary coolant activity to 0.05 μCi/gm is highly unlikely.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Illinois State official was notified of the proposed issuance of the amendments. The State official had no comments.

5.0 ENVIRONMENTAL CONSIDERATION

The amendments change a requirement with respect to the installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. The NRC staff has determined that the amendments involve no significant increase in the amounts and no significant change in the types, of any effluents that may be released offsite and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendments involve no significant hazards consideration and there has been no public comment on such finding (63 FR 11914). Accordingly, the amendments meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendments.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendments will not be inimical to the common defense and security or to the health and safety of the public.

Attachments:
1. Table 1 - Input Parameters for Braidwood, Unit 1, Evaluation of Main Steamline Break Accident
2. Table 2 - Thyroid Doses from Braidwood, Unit 1, Main Steamline Break Accident (Rem) (Values Calculated by NRC Staff)

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Date: September 3, 1998

TABLE 1

INPUT PARAMETERS FOR BRAIDWOOD, UNIT 1, EVALUATION OF MAIN STEAMLINE BREAK ACCIDENT

1. Primary Coolant Concentration of 3 μCi/gm of Dose Equivalent ^{131}I

<u>Pre-existing Spike Value (μCi/gm)</u>

^{131}I = 1.98
^{132}I = 2.22
^{133}I = 3.17
^{134}I = 0.48
^{135}I = 1.75

2. Volume of Primary Coolant and Secondary Coolant

Primary Coolant Volume (ft^3)	12,062
Primary Coolant Temperature (°F)	586.2
Secondary Coolant Steam Volume (ft^3)	3,889
Secondary Coolant Liquid Volume (ft^3)	2,070
Secondary Coolant Steam Temperature (°F)	544
Secondary Coolant Feedwater Temperature (°F)	440

3. TS Limits for DE ^{131}I in the Primary and Secondary Coolant

Maximum Instantaneous DE ^{131}I Concentration (μCi/gm)	3.0
Primary Coolant DE ^{131}I Concentration (μCi/gm)	0.05
Secondary Coolant DE ^{131}I Concentration (μCi/gm)	0.1

4. TS Value for the Primary to Secondary Leak Rate

Primary to secondary leak rate, maximum any SG (gpd)	150
Primary to secondary leak rate, total all 4 SGs (gpd)	600

5. Maximum Primary to Secondary Leak Rate to the Faulted and Intact SGs

Faulted SG (gpm @ room T/P)	132.8
Intact SGs (gpm/SG)	0.1

6. Iodine Partition Factor

Faulted SG	1.0
Intact SG	0.1

7. Steam Released to the Environment

Faulted SG (0 - 2 hours)	96,000 lbs
Faulted SG (2 - 40 hours)	33,945 lbs
Intact SGs (0 - 2 hours)	406,716 lbs
Intact SGs (2 - 8 hours)	939,604 lbs

8. Letdown Flow Rate (gpm) 75

9. Release Rate for 0.05 µCi/gm of Dose Equivalent ^{131}I

Release Rate (Ci/hr)	500X Release Rate (Ci/hr)
$^{131}I = 0.422$	211
$^{132}I = 3.09$	1550
$^{133}I = 1.06$	528
$^{134}I = 1.58$	790
$^{135}I = 1.07$	535

10. Atmospheric Dispersion Factors

	sec/m^3
EAB (0-2 hours)	$^*7.7 \times 10^{-4}$
LPZ (0-8 hours)	$^*7.9 \times 10^{-5}$
(8-24 hours)	$^*5.2 \times 10^{-5}$
(24-96 hours)	$^*2.1 \times 10^{-5}$
Control Room (0-8 hours)	6.24×10^{-3}
(8-24 hours)	3.16×10^{-3}
(24-96 hours)	8.42×10^{-4}

11. Control Room Parameters

Filter Efficiency (%)	
Air intake filter	99
Air recirculation filter	90
Volume (ft^3)	70,275
Makeup flow (cfm)	5400
Recirculation Flow (cfm)	44,550
Unfiltered Inleakage (cfm)	15
Occupancy Factors	
0-1 day	1.0
1-4 days	0.6
4-30 days	0.4

*NRC staff calculated values

TABLE 2

THYROID DOSES FROM BRAIDWOOD, UNIT 1, MAIN STEAMLINE BREAK ACCIDENT (REM) (VALUES CALCULATED BY NRC STAFF)

	DOSE	
LOCATION	**Pre-Existing Spike**	**Accident-Initiated Spike****
EAB	39.6*	23.3
LPZ	4.18*	2.57
Control Room **	4.50	0.30

* Acceptance Criterion = 300 rem thyroid
** Acceptance Criterion = 30 rem thyroid