UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 66 TO FACILITY OPERATING LICENSE NO. NPF-37

AND AMENDMENT NO. 66 TO FACILITY OPERATING LICENSE NO. NPF-66

COMMONWEALTH EDISON COMPANY

BYRON STATION, UNIT NOS. 1 AND 2

DOCKET NOS. STN 50-454 AND STN 50-455

1.0 INTRODUCTION

In its letter dated August 1, 1994, as supplemented on September 7, 1994, and September 17, 1994 (two letters), with clarifying information submitted by letters dated September 22, 1994, September 23, 1994, September 30, 1994, October 17, 1994, and October 24, 1994, the Commonwealth Edison Company (ComEd, the licensee), submitted a license amendment request to revise the Technical Specifications (TSs) for Byron Station, Unit 1. The requested amendment revises, in part, TS Sections 4.4.5.2, 4.4.5.4 and 4.4.5.5 and Bases Sections 3/4.4.5 to permit the use of a voltage-based steam generator tube (SG) plugging criteria for defects confined within the thickness of the tube support plates (TSPs). All of the proposed changes are applicable to the seventh operating cycle only.

The proposed voltage criteria pertains specifically to a form of SG tube degradation identified as outside diameter stress corrosion cracking (ODSCC) flaws. The proposed criteria: (1) permits flaws confined within the thickness of the TSPs with bobbin voltages less than or equal to 1.0 volt to remain in service; (2) permits flaws confined to within the thickness of the TSPs with bobbin voltages greater than 1.0 volt, but less than or equal to 2.7 volts, to remain in service if a rotating pancake coil (RPC) probe does not detect degradation; and (3) requires flaw indications confined to within the thickness of the TSPs with bobbin voltages greater than 2.7 volts to be plugged or repaired.

The clarifying information submitted September 22, 1994, September 23, 1994, September 30, 1994, October 17, 1994, and October 24, 1994, did not affect the initial no significant hazards consideration determination.

2.0 BACKGROUND

The staff is currently developing a generic interim position on voltage-based limits for ODSCC confined within the thickness of the TSPs. The staff has published several conclusions regarding voltage-based plugging criteria in draft NUREG-1477, "Voltage-Based Interim Plugging Criteria for Steam Generator Tubes" and in a draft generic letter titled "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter

Stress Corrosion Cracking." The latter document was published for public comment in the Federal Register on August 12, 1994. However, the staff is continuing to evaluate an acceptable generic position which will take into consideration public comments on the draft generic letter cited above, domestic operating experience under the voltage-based repair criteria, and additional data which have been made available from European nuclear power plants. The staff currently plans to document its final position on this matter in a generic letter. Pending completion and issuance of the staff's final generic position on the voltage-based SG tube repair criteria, the staff is continuing to evaluate voltage-based repair criteria proposals on a case-specific basis, as necessary, to ensure that there is adequate assurance of public health and safety. These criteria have previously been referred to as the interim plugging criteria. In our reviews of previous applications, these case-specific evaluations have limited the applicability of the voltage-based repair criteria to one cycle of operation.

In its letter dated August 1, 1994, the licensee requested an amendment to modify the TSs to allow the use of a voltage-based SG tube plugging criteria beginning with the forthcoming operating cycle, Cycle 7, which will start in late October 1994. Based on subsequent discussions between the licensee and the NRC staff, the licensee provided additional information and clarifications by letters dated September 7, September 17, 1994, September 22, 1994, September 23, 1994, September 30, 1994, and October 17, 1994. In its letter dated September 17, 1994, the licensee restricted its request for the implementation of the voltage-based repair criteria to Cycle 7 only.

The tube repair limits proposed by the licensee include a lower voltage repair limit of 1.0 volt for axially-oriented ODSCC flaws confined within the thickness of the TSPs in lieu of the present criteria in the Byron TS which have a depth-based limit of 40 percent through wall crack penetration. In addition, the repair limits allow bobbin indications between 1.0 and 2.7 volts (the latter value is identified as the upper voltage repair limit) to remain in service provided inspection of these indications with a RPC probe does not confirm that ODSCC degradation is present.

While the licensee's proposal is similar to that reviewed and approved for several other plants using Westinghouse SGs, it is the first proposal to reference the recently issued draft generic letter cited above. The draft generic letter continues to base the SG tube structural limit on maintaining a margin of safety of 1.43 against tube failure under postulated accident conditions and maintaining a margin of safety of three against burst during normal operation. The margin of safety of three against burst during normal operation is inherently satisfied for ODSCC flaws since the structural constraint provided during normal operation by the TSPs, which surround the SG tube degradation to which the voltage-based repair criteria applies, ensures that the SG tubes will maintain this margin of safety at these locations. To complement these two deterministic criteria, the staff's position is that the conditional probability of burst under accident conditions should also be calculated. The primary-to-secondary leakage from the SG tubes during a

postulated main steam line break (MSLB) is calculated in accordance with the methods described in the draft generic letter.

3.0 PROPOSED VOLTAGE-BASED REPAIR CRITERIA

Byron, Unit 1, TS Sections 4.4.5.2, 4.4.5.4, 4.4.5.5, and Bases Section 3/4.4.5, are revised by the modified amendment request of September 17, 1994, to specify the SG tube repair and leakage criteria for ODSCC confined within the thickness of the TSPs. The proposed changes to the tube repair and leakage criteria in the TSs specify, in part:

a. Implementation of the SG tube/tube support plate plugging criteria requires a 100 percent bobbin coil inspection for hot-leg TSP intersections and cold-leg TSP intersections down to the lowest cold-leg tube support plate with known ODSCC indications. The determination of the cold-leg TSP intersections having ODSCC indications is based on the performance of at least a 20 percent random sampling of the SG tubing inspected over their full length.

b. Degradation attributed to ODSCC within the bounds of the TSPs with a bobbin voltage less than or equal to 1.0 volt will be allowed to remain in service.

c. Degradation attributed to ODSCC within the bounds of the TSP with a bobbin voltage greater than 1.0 volt will be repaired or plugged except as noted in Item (d) below.

d. Indications of potential degradation attributed to ODSCC within the bounds of the TSPs with a bobbin voltage greater than 1.0 volt, but less than or equal to 2.7 volts, may remain in service if an RPC probe inspection does not detect ODSCC degradation. Indications of ODSCC degradation with a bobbin voltage greater than 2.7 volts will be plugged or repaired.

e. Certain intersections identified in Section 4.7 of WCAP-14046, Revision 1, will be excluded from application of the voltage-based repair criteria because it has been determined that these intersections may collapse or deform following a postulated loss-of-coolant accident plus safe shutdown earthquake (LOCA + SSE) event. (Refer to Section 4.3.3 of this evaluation.)

f. If, as a result of leakage due to a mechanism other than ODSCC at the SG TSP intersections, or some other cause, thereby causing an unscheduled mid-cycle inspection, the following repair criteria apply instead of Item (d) above. If the bobbin voltage is within expected limits, the indication can remain in service. The bobbin voltage limit for each individual SG tube TSP intersection is determined from the following equation:

$$V < \frac{\frac{\Delta t}{CL}(V_{SL} - V_{BOC}) + V_{BOC}}{1 + (.2)(\frac{\Delta t}{CL})}$$

where:

V = bobbin voltage of each SG tube TSP intersection measured during an unscheduled mid-cycle inspection
V_{BOC} = voltage at the beginning of cycle (BOC) of each SG tube TSP intersection
Δt = time period of operation to the unscheduled outage
CL = cycle length (full operating cycle length where the operating cycle is the time between two scheduled steam generator inspections)
V_{SL} = 4.5 volts for 3/4-inch tubes

g. For implementation of the voltage-based repair criteria to SG tube TSP intersections, notification of the NRC staff prior to returning the SGs to service is required should any of the following conditions arise:

1. If the estimated leakage based on the actual measured end-of-cycle (EOC) voltage distribution would have exceeded the maximum permissible SG leakage limit (for the postulated MSLB using licensing basis assumptions) during the previous operating cycle.

2. If circumferential crack-like indications are detected at the TSP intersections.

3. If indications are identified that extend beyond the confines of the TSPs.

4. If the calculated conditional burst probability exceeds 1×10^{-2}. Additionally, an assessment of the safety significance of this condition should be provided.

In addition to the TS revisions cited above, the licensee also made the following commitments for implementing the voltage-based repair criteria:

1. All flaw indications with bobbin voltages greater than 1.0 volt will be inspected using an RPC probe.

2. Tubes with bobbin dent voltages exceeding 5.0 volts and with large mix residuals are to be inspected with an RPC and any RPC flaw indications will be plugged or repaired.

3. The repair criteria will not be applied to flow distribution baffle plate intersections.

4. A sufficient number of SG tubes having a minimum of six TSP intersections will be removed for destructive examination. The results of these examinations will be reported within 90 days following restart.

5. Tubes with known leaks will be repaired prior to returning the SGs to service.

6. SG tube integrity data (i.e., voltage distributions and leak/burst evaluations) will be provided to the NRC within 90 days following restart.

7. Only a 0.610-inch diameter bobbin coil probe will be used during the SG inspection implementing the voltage-based repair criteria.

8. The NRC will be promptly notified if any primary water stress corrosion cracking (PWSCC) indications are detected at the TSP elevations during the SG inspections.

9. The conditional probability of burst calculation will consider parametric uncertainty.

10. The licensee will initiate a mid-cycle SG tube inspection no later than September 15, 1995.

4.0 EVALUATION

4.1 Inspection Issues

In support of the proposed voltage-based repair limits, the licensee proposes to utilize the eddy current test guidelines provided in its license amendment request dated August 1, 1994, and as later supplemented. The inspection criteria are intended to ensure that the inspection scope, data acquisition, and data analysis are performed in a manner consistent with the methodology utilized to develop the permissible voltage limits. The proposed guidelines define, in part, the bobbin specifications, calibration requirements, specific acquisition and analyses criteria, and flaw recording guidelines to be used for the inspection of the SGs.

The inspections to be performed as part of the voltage-based repair criteria include both bobbin coil and RPC examinations. Bobbin coil examinations will be performed for 100 percent of the hot-leg tube support plate intersections and cold-leg intersections down to the lowest cold-leg TSP with known ODSCC. The lowest cold-leg TSP with known ODSCC will be determined by randomly examining at least 20 percent of all of the SG tubes over their full length. RPC examinations will be performed to permit additional characterization of the flaws found with the bobbin coil probe and to inspect intersections with significant bobbin interference signals due to either copper depositions,

dents, or large mix residuals which may impair the ability of the bobbin coil probe to detect flaws or which may unduly affect the bobbin voltage measurement.

With respect to flaw characterization, a key purpose of the RPC inspections is to ensure the absence of detectable crack-like circumferential indications and detectable indications extending outside the thickness of the TSPs. The voltage-based repair criteria are not applicable to intersections exhibiting such indications; i.e., circumferential indications and indications extending outside the TSPs. Special reporting requirements pertaining to the finding of such indications have been proposed by the licensee for incorporation into the TSs. RPC examinations will be performed for: (1) all indications exceeding 1.0 volt as measured by the bobbin coil; (2) all dent signals greater than 5.0 volts; and (3) all intersections where the mix residual could cause a 1.0 volt bobbin signal to be missed or misread. Any flaw-like indications found at intersections with dent signals greater than 5.0 volts or large mix residuals will require SG tube repair. Since the licensee does not have copper in the secondary system, copper deposits are not expected to be observed and, hence, RPC sampling of such locations is not applicable.

As discussed above, TSP locations with bobbin dent voltages above 5.0 volts will be inspected with an RPC probe. Inspections of dented intersections are performed, in part, as a result of: (1) the possible masking effect the dent may have on the detection of flaw indications; (2) the possible development of PWSCC flaws at these locations; and (3) the possible development of circumferential cracks at these locations. With respect to masking flaw indications, it is anticipated that flaw signals on the order of 1.0 volt would have phase angles that fall within the flaw reporting range, even if the bobbin dent voltage was as high as 5.0 volts, based on a vectorial combination of the eddy current signals attributed to the flaw and to the dent. As a result, the requirement to RPC inspect all intersections with bobbin dent voltages in excess of 5.0 volts provides reasonable assurance that any structurally significant ODSCC indications will be detected and repaired. With respect to the occurrence of circumferential cracking at the TSP elevations, the RPC sampling plan will permit identification of these types of flaws.

With respect to the occurrence of PWSCC at dented TSP intersections, the potential exists for axial PWSCC to occur at TSP intersections where the bobbin dent voltage is less than 5.0 volts. Most frequently, these types of indications (i.e., indications representative of axially oriented PWSCC) have been: (1) found at TSPs with significant denting; (2) known to occur at 180° spacing as two axial indications due to the stresses in the tube; and (3) known to occur within the TSP but occasionally extending outside the TSP. Axial PWSCC is not presently considered to be included in the voltage-based repair criteria. As a result of this and the potential for PWSCC to occur at dented intersections less than 5.0 volts, the licensee has proposed to: (1) implement an RPC sampling plan at locations where the bobbin dent voltage is between 2.5 and 5.0 volts; (2) inspect all intersections where the bobbin dent voltage is greater than 5.0 volts; and (3) expand the RPC scope for dents

below 5.0 volts if any flaw is detected in the original random RPC sample. Furthermore, the licensee has committed to promptly notify the NRC of any PWSCC indications identified at the TSP elevations. In addition, the licensee has instructed the eddy current analysts to be aware of the potential for PWSCC at dented TSP locations. The analysts were also instructed to report occurrences of axial PWSCC. The staff finds this sampling plan adequate to detect the onset of axial PWSCC at dented TSP locations. The staff also notes that axial PWSCC frequently extends outside the TSP intersections, making it more likely to be detectable with the bobbin coil. This provides added confidence that if extensive axial PWSCC is present, it will be detected.

With respect to data acquisition and analysis, the licensee's eddy current guidelines either contain requirements or guidance pertaining to: (1) recording all indications regardless of voltage amplitude; (2) controlling probe wear by the use of a probe wear standard; (3) calibrating the bobbin coil probes; and (4) using a transfer standard to ensure consistency between the voltages measured in the field and the voltages measured in the laboratory as part of the development of the voltage-based approach.

The staff notes that there are several outstanding technical issues with respect to the inspection guidelines, as documented in previously issued NRC documents (e.g., in draft NUREG-1477 and in the draft generic letter cited above) which will be resolved prior to issuing the final generic letter on this matter. These outstanding issues include, in part: (1) limits on new probe variability; (2) the need to reinspect all tubes since the last successful probe wear check; (3) the need to calibrate the bobbin coil on 4-100 percent holes versus 4-20 percent holes; and (4) the capabilities and limitations of the 1-coil, 2-coil, and 3-coil RPC probes. However, the staff concludes that the inspection guidelines submitted by the licensee are acceptable in that the proposed repair criteria are limited to one cycle, and the calibration, recording, and analysis requirements are consistent with the methodology used in the development of the data bases and supporting evaluations.

4.2 Tube Integrity Issues

The thin-walled tubing of the SGs constitutes more than half of the reactor coolant pressure boundary (RCPB). Accordingly, maintenance of the structural and leakage integrity of this portion of the RCPB is a requirement under Title 10 of the Code of Federal Regulations, Part 50 (10 CFR Part 50), Appendix A. Specific requirements governing the maintenance of SG tube integrity are contained in a plant's TSs and Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code). Included in these requirements is the need for periodic inservice inspection of the tubing, flaw acceptance criteria (i.e., repair limits for plugging or sleeving), and primary-to-secondary leakage limits. These specific requirements, coupled with the broad scope of plant operational and maintenance programs, have formed the basis for assuring adequate SG tube integrity.

Flaw acceptance criteria, termed plugging/repair limits, are contained in a plant's TSs. The purpose of the TS repair limits is to ensure that SG tubes with known flaws but accepted for continued service, will retain adequate structural and leakage integrity during normal operating, transient, and postulated accident conditions, consistent with General Design Criteria (GDC) 14, 15, 30, 31 and 32 of 10 CFR Part 50, Appendix A. Structural integrity refers to maintaining adequate margins against gross failure, rupture, and collapse of the SG tubing. Leakage integrity refers to limiting primary-to-secondary SG leakage within acceptable limits.

The traditional strategy for accomplishing the objectives of the GDC cited above, related to SG tube integrity, has been to establish a minimum wall thickness requirement in accordance with the structural criteria of Regulatory Guide (RG) 1.121, "Basis for Plugging Degraded PWR Steam Generator Tubes." Allowances for eddy current measurement error and flaw growth between inspections have been added to the minimum wall thickness requirements, consistent with the guidelines in RG 1.121, to arrive at a depth-based repair limit. Development of the minimum wall thickness requirements to satisfy RG 1.121 was governed by analyses for uniform thinning of the SG tube walls in the axial and circumferential directions. The assumption of uniform thinning conservatively bounds the degrading effects of all SG tube flaw types currently occurring in nuclear power plants and is the basis of the standard 40 percent depth-based plugging limit incorporated into the Byron 1 TSs. However, the 40 percent repair limit is conservative for highly localized flaws such as pits and short cracks. In particular, the 40 percent depth-based repair limit is conservative for ODSCC which occurs at the TSP intersections.

Enforcement of a minimum wall thickness requirement for the SG tubes would implicitly serve to ensure leakage integrity during normal operation and postulated accidents, as well as structural integrity. It has been recognized, however, that defects, especially cracks, may occasionally grow entirely through-wall and develop small leaks. For this reason, limits on the allowable primary-to-secondary leakage have been established in a plant's TSs to ensure timely plant shutdown before adequate structural and leakage integrity of an affected SG tube is impaired.

The voltage-based tube repair limits at TSP intersections proposed by the licensee consist of voltage amplitude criteria rather than the traditional depth-based criteria. Thus, the proposed repair criteria represents a departure from the past practice of explicitly enforcing a minimum wall thickness requirement.

The industry-wide data base from examinations of SG tubes pulled from a number of SGs in operating nuclear power plants shows that for bobbin indications exceeding 1.0 volt (i.e., the lower voltage repair limit), maximum crack depths range between 50 percent and 100 percent through-wall. The likelihood of through-wall or near through-wall crack penetrations appears to increase with increasing voltage amplitude. For indications at or near 2.7 volts, the maximum crack depths have been found to generally range between 90 percent and

100 percent through-wall. Many of the SG tubes which will be allowed to remain in service under the voltage-based repair criteria proposed by the licensee, may have, or develop, through-wall or near through-wall crack penetrations during the upcoming operating cycle, thus creating the potential for leakage during normal operation and during a postulated MSLB accident. The staff's evaluation of the proposed repair criteria from a structural and leakage integrity standpoint is provided in Sections 4.3 and 4.4 of this evaluation.

Although the voltage-based repair limits ensure adequate structural and leakage integrity, the NRC staff recognizes that overall margins have been reduced when compared to the margins associated with the existing depth-based repair limit. Because of the increased likelihood of through-wall cracks developing in service, the staff has included provisions for augmented SG inspections, as discussed in the previous section, and more restrictive operational tube leakage limits, as discussed below.

4.3 Structural Integrity

4.3.1 Deterministic Structural Integrity Assessment

The licensee has proposed a burst pressure/bobbin voltage correlation to demonstrate that bobbin indications satisfying the 1.0 volt lower voltage repair criterion, would retain adequate structural margins, consistent with the guidelines in RG 1.121. This correlation was developed from both pulled SG tube data from other plants (using pre-pull bobbin voltages) and laboratory tube specimens containing ODSCC flaws. The bobbin voltage data used to construct the burst pressure/bobbin voltage correlation were normalized and are consistent with the calibration standard voltage set-ups and voltage measurement procedures to be used by the licensee during the SG inspections.

During the current refueling outage, the licensee will remove from the SGs, a number of SG tubes which will have a minimum of six TSP intersections with indications of ODSCC for leak and burst testing and destructive metallographic examination. These tests and examinations are being performed, in part, to confirm that the degradation being observed at the TSP elevations is predominantly axially oriented ODSCC. These tests of the pulled SG tubes will also increase the supporting data bases for the burst pressure, probability of leakage, and conditional leak rate correlations. The metallographic examinations will provide added assurance that the degradation being observed at Byron, Unit 1, is consistent with the data used to support the development of the voltage-based tube repair criteria (i.e., demonstrate that the flaw indications are ODSCC).

The voltage repair criteria previously approved by the staff for other plants have been set deterministically to ensure that tubes will retain adequate structural integrity during the full range of normal, transient, and postulated accident conditions with adequate allowance for eddy current test uncertainty and the flaw growth projected to occur during the next operating cycle. Because the voltage-based repair criteria addresses tubes affected

with ODSCC confined within the thickness of the TSPs during normal operation, the staff has concluded that the structural constraint provided by the TSPs ensures that all SG tubes to which the voltage-based criteria applies, will retain a margin of three with respect to burst under normal operating conditions, consistent with the guidelines in RG 1.121. For a postulated MSLB accident, however, the TSPs may displace axially during blowdown such that the ODSCC affected portion of the tubing may no longer be fully constrained by the TSPs. Accordingly, it is conservative to consider the ODSCC affected regions of the SG tubes to be free standing tubes for the purpose of assessing burst integrity under MSLB postulated conditions.

The allowable EOC voltage which ensures a margin of 1.43 with respect to burst under postulated MSLB conditions (i.e., a differential pressure of 3660 psi) in accordance with RG 1.121, is based on the lower 95 percent prediction interval of the burst pressure/bobbin voltage correlation, adjusted for lower bound material properties evaluated at the 95/95 confidence level. This voltage limit is about 4.5 volts for the 3/4-inch diameter SG tubing used in the Byron 1 SGs. The difference between the 4.5 volt allowable EOC voltage and the 1.0 volt repair criterion represents an allowance of 3.5 volts for voltage growth (i.e. ODSCC flaw growth) during the forthcoming fuel cycle. It also includes an allowance for eddy current voltage measurement variability (i.e., the repeatability error) during the SG inspection.

To demonstrate the adequacy of the voltage-based repair criterion, the largest RPC confirmed indication which may be left in service (i.e., a 1.0 volt indication), was analyzed by the staff to determine if this indication would grow to the point that the structural voltage limit (i.e., 4.5 volts) is exceeded. In this analysis, a 1.0 volt bobbin indication is assumed to grow at a rate equal to the maximum growth rate observed during the latest cycle for which data is available; i.e., 2.6 volts for Cycle 5 which was 1.127 EFPY in duration. It is also assumed that the 1.0 volt indication was undersized by 20 percent (i.e., the 95 percent cumulative probability on the non-destructive examination (NDE) uncertainty). The EOC voltage estimate in this analysis is 4.2 volts for the 1.3 EFPY planned for Operating Cycle 7. This EOC voltage compares favorably with the structural voltage limit of 4.5 volts determined from the burst pressure versus bobbin voltage correlation.

The proposed lower limit 1.0 volt repair criterion is applicable to all bobbin indications confirmed by RPC or which have not been RPC inspected. The licensee has also proposed a 2.7 upper voltage repair limit applicable to bobbin indications which have been RPC inspected, but for which the RPC failed to confirm the bobbin indication. This 2.7 volt limit was determined from the allowable EOC voltage (i.e., ~4.5 volts), allowing for average growth rates of 50 percent of the BOC voltage amplitudes and the upper 95 percent confidence estimate for voltage variability (i.e., 20 percent of the BOC voltage amplitude). The average growth rate determined by the licensee for Cycle 5 is bounded by the 50 percent average growth rate assumed in the analysis discussed above. Additionally, the eddy current data analysis guidelines should limit the variability in the voltage measurements to that which was assumed (i.e., 20 percent of the BOC amplitude).

The staff has evaluated the acceptability of the upper voltage repair limit for indications below this limit which may be left in service if detected by the bobbin coil probe but not confirmed to be flaw-like by the RPC probe. Short and/or relatively shallow cracks detected by the bobbin coil may sometimes not be detectable by the RPC probe, although the RPC probe is considered by the staff to be more sensitive to those flaws which are of structural significance (i.e., those which are longer and deeper). Furthermore, the burst strength of SG tubing affected by predominantly axially-oriented ODSCC at the TSP elevations is not a unique function of the bobbin voltage. Rather, for a given voltage, there is a statistical distribution of possible burst strengths, as indicated in the burst pressure/bobbin voltage correlation. The staff believes that the burst pressure for bobbin indications which were not confirmed to be flaw-like by the RPC probe will tend to be at the upper end of the burst pressure distribution (i.e., exhibit a burst pressure higher than the mean value determined in the statistical analysis). Specifically, ODSCC which is not detectable by the RPC probe is believed to be less likely to affect the tube structural and leakage integrity during the forthcoming operating cycle than ODSCC which is detectable by both the bobbin coil and the RPC probe. In addition, the burst and leakage potential for bobbin indications accepted for continued service under the 2.7 volt criterion have been directly considered in the probability of burst and leakage assessments described below, with no credit given to the fact that the RPC probe failed to confirm the indications. Based on these considerations, the staff finds that the upper voltage repair limit of 2.7 volts for indications which may be left in service if detected by bobbin inspection but not confirmed by the RPC, is acceptable.

The licensee discussed in its letter dated September 17, 1994, its basis for deciding to perform a hot chemical cleaning of the Byron 1 SGs at the start of the current refueling outage (i.e., B1R06). This discussion also included its evaluation of the impact of chemical cleaning on the subsequent implementation of the voltage-based repair criteria. The staff notes that the removal of deposits during this chemical cleaning process can be postulated to change the eddy current signals indicating ODSCC flaws in the SG tubing. Furthermore, this cleaning process could ultimately affect the detectability and sizing of ODSCC flaws. Accordingly, the staff discussed this matter with the licensee to assess the possible affects of this chemical cleaning process on the planned eddy current examinations. The staff's questions arose from recent experience at Palo Verde, Units 2 and 3, in which there was an increase in detectability and a general increase in the voltage levels of the defects in only one of the four SGs which were chemically cleaned. In the one SG which exhibited the detectability shift at Palo Verde, the majority of the indications exhibited a voltage increase following chemical cleaning. A small percentage exhibited a voltage decrease.

ComEd expects that if the chemical cleaning process has an affect at all on the Byron 1 SGs, it would most likely result in more flaws being detected and the distribution of flaw sizes would be skewed to slightly larger indications. The licensee, therefore, believes that the overall result of the chemical cleaning process will be a more conservative structural and leakage integrity

assessment of the SG tubing for the forthcoming cycle. The licensee believes that any decrease in the size of an eddy current indication following chemical cleaning is expected to be the result of other inspection factors not associated with the cleaning; for example, normal eddy current variability due to probe wear and analyst variability.

A systematic change in the voltage readings, whether it is an increase or decrease, raises potential generic questions with respect to implementation of the voltage-based tube repair criteria. Potential concerns include whether: (1) the data bases used in the development of the voltage-based repair criteria adequately bound the varying degrees of tube fouling present in the field; and (2) the effect of chemical cleaning, or the lack thereof, on the voltage growth distribution not only in the short-term but also in the long-term. The staff notes that if the SG chemical cleaning process performed at Byron, Unit 1, does result in a voltage increase (similar to what occurred at the Palo Verde units), it would be expected that the growth rate distribution would most likely result in a more conservative structural and leakage integrity assessment for the forthcoming operating cycle (Cycle 7). The staff further notes that any increase in bobbin voltage would most likely result in more tubes being identified for repair, which is also more conservative. The staff, therefore, concludes that the chemical cleaning process implemented at Byron, Unit 1, should not have an adverse affect on the implementation of the voltage-based repair criteria for one cycle. Furthermore, removing tubes from the SGs following the chemical cleaning may also provide confirmatory insights on the effects of chemical cleaning, if any, on the integrity and inspectability of the SG tubing.

The staff notes, however, that the continued adequacy of the conservatism of the voltage growth rate distribution and the tube repair criteria will need to be evaluated for any subsequent voltage-based repair criteria requests because of the chemical cleaning performed during the present refueling outage. The staff also notes that further quantitative evaluation to support the licensee's conclusion that any decrease in voltage readings following chemical cleaning is most likely attributable to normal eddy current variability, may be required for future analyses.

4.3.2 Probabilistic Structural Integrity Assessment

A probabilistic analysis for the potential for SG tube ruptures, given a MSLB, must also be performed. The need for this analysis, which supplements the deterministic analysis discussed above, is dictated by the following considerations:

1. The deterministic analysis does not consider the tail of the burst pressure distribution beyond the lower 95 percent prediction interval used to determine the maximum allowable EOC voltage. Given the large numbers of indications being accepted for continued service with the 1.0 volt criterion, a probabilistic analysis ensures that the use of the 95 percent prediction interval value in lieu of the 99 percent or 99.9

percent values does not lead to a significant likelihood of SG tube rupture, given a MSLB.

2. The deterministic assessment ignores the burst and leakage potential of bobbin indications between 1.0 volt and 2.7 volts for which the RPC probe failed to confirm the indication. The probabilistic assessment, however, considers the burst potential of these indications with no credit given for the lack of confirmation by the RPC probe of the presence of these indications.

3. The deterministic analysis does not account for bobbin voltage indications missed by the data analysts. The staff concluded in draft NUREG-1477 and in the draft generic letter cited above that a probabilistic assessment is required in order to address the burst potential of indications missed by the data analysts.

4. The deterministic analysis does not consider the cumulative effect of the entire distribution of indications accepted for continued service. Employing a probabilistic analysis, however, ensures that all indications accepted for continued service are accounted for in determining the overall probability of burst, given a MSLB.

5. The deterministic analysis does not consider the tails of the material properties distribution and the eddy current voltage variability distributions. The probabilistic analysis does include the entire distribution of material properties and voltage variability.

To perform this probabilistic analysis, the EOC distribution of indications must be determined. Consistent with the approach recommended in the draft generic letter on voltage-based repair criteria, the BOC distribution used in the determination of the EOC distribution involves adjusting the indications detected during the inspection by the probability of detection (POD), where the POD is assumed to have a constant value of 0.6, independent of voltage. The net effect of this assumption is that the distribution of detected bobbin indications is scaled up by a factor of 1/POD. After this POD scaling is made, indications removed from service by tube repair (i.e., either by plugging or sleeving) are subtracted from this distribution to yield the assumed BOC distribution. The EOC distribution is then determined by combining the voltage measurement uncertainty distribution, the voltage growth rate distribution, and the BOC voltage distribution using Monte Carlo techniques. For each of the resultant EOC voltages determined by the above analysis, the distribution of burst pressures as a function of bobbin voltage along with a distribution of material properties is sampled by Monte Carlo techniques to yield a distribution of burst pressures for the EOC voltage distribution. The conditional probability of burst, given a MSLB, can then be determined by dividing the number of times the Monte Carlo analysis yields a burst pressure below the differential pressure resulting from a postulated MSLB for the EOC voltage distribution, by the total number of samples.

The POD scaling approach cited above is reasonably consistent with reported operating experience with ODSCC to date in terms of accounting for the projected distribution of indications at EOC which were not previously detectable at BOC. However, operating experience for ODSCC flaws confined within the thickness of the TSPs, indicates that the measured maximum EOC bobbin voltages generally do not exceed 4 or 5 volts. Although there are known cases where indications on the order of 3 volts have not been detected, there is very little experience regarding the likelihood of not detecting bobbin voltage indications between 3 and 10 volts. The industry believes that the numerical value of the POD is substantially higher than 0.6 for indications exceeding 1.0 volt, based, in part, on data collected from the Electric Power Research Institute (EPRI) performance demonstration program. However, pending further staff review, the staff believes a POD value of 0.6 is appropriate for this particular voltage-based repair criteria application.

The licensee will perform the probabilistic analysis discussed above which assumes that the degradation occurs in the free span between the TSPs, thereby ignoring the potential constraining effects of the TSPs. In addition, this analysis will be performed in a manner which considers the uncertainty in the parameters for the supporting correlations (e.g., burst pressure/bobbin voltage correlation). The results of the probabilistic analysis will be compared to a threshold value of $1x10^{-2}$. This threshold value provides assurance that there is a low probability of SG tube burst considering the assumptions of the calculation. There is also further assurance on this issue derived from the consideration that the threshold value is one-fifth the value considered in the staff's generic risk assessment for SGs contained in NUREG-0844, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, and A-5 Regarding Steam Generator Tube Integrity." Failure to meet the $1x10^{-2}$ threshold indicates that ODSCC flaws confined within the thickness of the TSPs could contribute more than one-fifth to the overall conditional probability of SG tube rupture from all forms of SG degradation that was assumed and found to be acceptable in NUREG-0844. In addition, exceeding this threshold provides an indication that one or more tubes may not maintain the RG 1.121 safety margin guidelines for the entire forthcoming operating cycle. As a result of these considerations, if the threshold value cited above is exceeded, an assessment of the safety significance of this condition will be provided to the NRC prior to returning the Byron 1 SGs to service. The staff finds this requirement in the proposed TSs to be acceptable.

After the staff had completed its review of the licensee's commitment to perform the safety assessment described above and found it acceptable, the licensee submitted the results of this analysis in its letter dated October 17, 1994, in accordance with the amended TSs. While the staff has not completed its review of this submittal, it notes that the licensee's conditional tube burst probability is $1.5x10^{-2}$ at BOC and $3.3x10^{-2}$ at EOC. The staff believes that this projected EOC conditional tube burst probability is sufficiently high to warrant a mid-cycle SG inspection.

4.3.3 Combined Accident Loadings

In its letter dated September 30, 1994, the licensee submitted its justification for its prior statement that its evaluation of the effect of combined safe shutdown earthquake (SSE) and loss-of-coolant accident (LOCA) loads as well as the combination of SSE plus MSLB loads, was conservative. The licensee had originally made this statement in Attachment H (WCAP-14046, Revision 1), to its letter dated August 1, 1994. This evaluation of the effects of the load combinations cited above on the structural integrity of the SG tubes is required to satisfy the requirements of GDC 2 of Appendix A to 10 CFR Part 50. Specifically, a combined LOCA plus SSE must be evaluated for potential yielding of the TSPs which could result in subsequent deformation of the SG tubes. If significant SG tube deformation should occur, the primary flow area could be reduced. Additionally, relatively small through-wall or near through-wall cracks in the SG tubes could open up which might create the potential for leakage (i.e., secondary-to-primary leakage) under LOCA conditions. In-leakage during a LOCA would pose a potential concern since it may cause an increase in the core peak clad temperature (PCT). The most limiting accident conditions for SG tube deformation considerations result for the combination of SSE and LOCA loads. The seismic excitation defined for the SGs is in the form of acceleration response spectra at the SG supports.

Inasmuch as the licensee has not performed a plant-specific LOCA analysis of the structural loads on the TSPs for Byron 1, it made a conservative estimate of the SG tubes to be excluded from the application of the voltage-based repair criteria. The basis for this estimate was a previous analysis for a plant with the same SG model as at Byron 1; i.e., a Westinghouse Model D4. This analysis performed per the guidelines of RG 1.121, was found to result in the potential for nine SG tubes per wedge to collapse at a total TSP load of about 270,000 pounds. A prior conservative estimate of the number of SG tubes which would collapse at this other plant was 27 tubes at the limiting wedge group.

Based on the seismic spectra for two nuclear power plants with a Westinghouse Model D3 SG, the maximum TSP seismic loads were calculated to range from 100,000 to 130,000 pounds. The staff notes that: (1) these seismic analyses of the Model D3 SGs were performed using seismic spectra which are different from the seismic floor spectra for the Byron Station, and (2) these seismic analyses were performed on a SG model different than that at Byron 1. The maximum number of SG tubes per TSP affected by the combined SSE plus LOCA loads for the larger of the two seismic spectra, ranged from about 14 to 20 SG tubes. On this basis, the licensee concluded that excluding 27 SG tubes from the potential relief offered by the voltage-based repair criteria, was conservative with the possible exception of the highest elevation TSP.

The licensee's justification for considering the exclusion of 27 SG tubes to be conservative even for the top TSP, is that it believes the Byron 1 plant-specific LOCA loads on the TSPs for a Model D4 SG will affect significantly fewer SG tubes than the LOCA loads in a Model D3 SG, based on a large break LOCA event. The licensee's position is that the leak-before-break (LBB)

design criteria for the Byron 1 primary piping will limit the LOCA loads that will be imposed on the TSPs in the Byron 1 SGs under postulated SSE plus LOCA loads. The licensee believes that the loads on the top TSP caused by the rarefaction pressure wave associated with a postulated LOCA, will be lower for those plants whose primary piping is designed to LBB criteria. Specifically, an analysis of another SG model, considering LBB, demonstrated a significant reduction in the structural loads on the top TSP induced by a rarefaction wave. This large reduction in the loading on the top TSP in combination with the fact that very few ODSCC flaws are found at the top TSP, forms the basis for the licensee's conclusion regarding the overall conservatism in excluding 27 SG tubes from the application of the voltage-based repair criteria.

The staff performed a limited review of the licensee's September 30, 1994, submittal on this matter. Based on its review, the staff finds that there is reasonable assurance that the exclusion of 27 SG tubes proposed by the licensee, is acceptable. The staff, however, requires that the licensee perform a plant-specific analysis of the effect of the combined SSE plus LOCA loads on the structural integrity of the Byron 1 SG tubes at the SG wedge area as discussed in Section 4.7 of WCAP-14046, Revision 1. Futhermore, the staff's position regarding the application of LBB considerations in accordance with GDC 4 of Appendix A to 10 CFR Part 50, is that this is related to the exclusion of dynamic effects resulting from pipe rupture (i.e., pipe whip and jet impingement loads) and is not intended to be used for the reduction of structural loads induced on structures and components by a postulated LOCA.

4.4 Leakage Integrity

An important implication of voltage-based SG tube repair criteria is that the criteria may permit tubes to have, or to develop, through-wall or near through-wall cracks during the forthcoming operational cycle, thus creating the potential for primary-to-secondary leakage during normal operation, transients, or postulated accidents. Accordingly, the leakage integrity of these SG tubes, in addition to their structural integrity, must be assessed.

The staff finds that adequate leakage integrity during normal operating conditions is assured by the limits on allowable primary to-secondary leakage. Adequate leakage integrity during transients and postulated accidents is demonstrated by showing that for the most limiting accident, assumed to occur at the end of the next operating cycle, the resulting leakage will not exceed a rate that will result in offsite dose limits being exceeded. The radiological consequences of this is discussed in Section 4.5.

4.4.1 Normal Operational Leakage

Implementation of the voltage-based tube repair criteria requires a reduction in the maximum allowable TS reactor coolant system leakage limits. Specifically, the present TS limit of 500 gallons per day (gpd) limit for primary-to-secondary leakage through any one SG must be reduced to 150 gpd,

and the limit on the total primary-to-secondary leakage through all four SGs must be reduced to 600 gpd from 1.0 gallon per minute (gpm) which is 1440 gpd.

The present 500 gpd limit per SG is intended to ensure that through-wall cracks which leak at rates up to this limit during normal operation will not propagate and result in SG tube rupture under postulated accident conditions consistent with the guidelines in RG 1.121. Development of the 150 gpd per SG leakage limit has utilized the extensive industry data base regarding burst pressure as a function of crack length and leakage during normal operation. Based on leakage evaluated at the lower 95 percent confidence interval for a given crack size, the 150 gpd limit would be exceeded before the crack length reaches the critical crack length for the differential pressure that would occur across the SG tube under a postulated MSLB. Based on nominal, best estimate leakage rates, the 150 gpd limit would be exceeded before the crack length reaches the critical crack length corresponding to a burst pressure of three times normal operating pressure.

The reduced SG leakage limits to be adopted as a requirement for implementation of the voltage-based tube repair criteria are more restrictive than the present limits in the Byron 1 TSs which are 500 gpd per SG and 1440 gpd for all SGs, in order to provide a margin of safety against rupture. This reduction in the SG maximum allowable leakage limits is intended to provide an additional margin in the event that a crack grows at a rate much greater than expected or which may unexpectedly extend outside the thickness of the TSPs. Pending review and approval of a tube sleeving amendment submitted by the licensee on June 3, 1994, which incorporates the reduced leak rate limits cited above into the Byron 1 TSs, the licensee has implemented these reduced leakage SG limits administratively. These administrative leak rate limits require plant shutdown if the primary-to-secondary leakage through any one SG reaches 150 gpd. The staff finds that administratively implementing the reduced maximum permissible operating SG leakage limits (i.e., 150 gpd per SG) is an acceptable short-term option pending issuance of the sleeving amendment and incorporation of the revised SG leakage limits into the Byron TSs. Issuance of this amendment is expected in November 1994.

4.4.2 Accident Leakage

The licensee has proposed a model for calculating the SG tube leakage from the faulted steam generator during a postulated MSLB which consists of two major components: (1) a model predicting the probability that a given indication will leak as a function of voltage (i.e., the probability of leakage (POL) model); and (2) a model predicting this leak rate as a function of voltage, given that leakage occurs (i.e., the conditional leak rate model).

In the POL model, the probability that a given indication will leak is presented as a function of the bobbin coil voltage of that indication. The data is separated into two categories (i.e., indications which leak during a MSLB and those which do not). While various functional forms can be fitted to the experimental data, the staff has concluded that a single functional form, the log-logistic, is acceptable for the purpose of assessing MSLB-induced SG

tube leakage. The staff believes that any non-conservatism associated with the use of the log-logistic model, as compared to other functional forms, is small compared to the conservatism inherent in the existing methodology for calculating the SG tube leakage induced by a postulated MSLB and calculating radiological consequences of this leakage. In addition, the differences in the POL functional forms are considered to be less significant when the leakage is calculated using a linear leak rate model, as discussed below, instead of the constant leak rate model contained in draft NUREG-1477. This document treats leakage as independent of voltage.

Regarding the conditional leak rate model, a correlation between the SG tube leak rate and bobbin voltage data, based on a linear regression fit of the logarithms of the data, has been developed. The staff provided statistical criteria in the draft generic letter cited above on voltage-based repair criteria which permits licensees to use such a correlation if the correlation can be statistically justified at a 95 percent confidence level (i.e., a p-value of 5 percent). The licensee has proposed to use such a correlation for calculating the leakage during postulated accident conditions. The staff concludes that using a linear relationship between the logarithms of the leak rate and bobbin voltage is appropriate in the calculation of the primary-to-secondary SG tube leakage during a postulated MSLB, provided the statistical criteria delineated in the draft generic letter on this subject are met. The staff further notes that the data bases used in such evaluations should be consistent with the data bases discussed in the Safety Evaluation issued in conjunction with Amendment No. 54 to Facility Operating License No. NPF-72 for Braidwood Station, Unit No. 1, dated August 18, 1994. The data base referenced in Amendment No. 54 will be revised and updated, as appropriate, to include other pulled SG tube test data available since that amendment was issued.

The licensee has proposed a method for determining the primary-to-secondary SG tube leakage during a postulated MSLB which involves a Monte Carlo technique which accounts for the regression parameter uncertainties. Based on its analysis of this model, the staff has concluded that this Monte Carlo methodology is appropriate and consistent with the draft generic letter on voltage-based repair criteria. This method involves:

1. Determining random versions of the POL and leak rate correlations to account for the uncertainty in the regression parameters (i.e., parameter uncertainty).

2. Using the regression parameters from Step 1 to determine the leak rate for each flaw indication in the estimated EOC voltage distribution. The EOC voltage distribution used in this calculation is the same as that discussed in Section 4.3.2.

3. Calculating the sum of the individual leak rates determined in Step 2 to obtain a value of the total SG leak rate.

4. Repeating Steps 1, 2, and 3 many times (e.g., 10,000) to obtain a distribution of the total SG leak rates.

5. Ordering the distribution of total leak rates in Step 4 in ascending order, and taking the 95th quantile at a 95 percent confidence level as the primary-to-secondary SG leakage during a postulated MSLB. This is the value used in assessing the leakage integrity of the SG tubing.

The licensee has estimated the allowable steam generator leak rate to be 12.5 gpm in the faulted SG. This value is consistent with maintaining the radiological consequences of a release outside containment to within a small fraction of the guideline values in 10 CFR Part 100. As a result, if the estimated primary-to-secondary leakage during a postulated MSLB at EOC is less than the 12.5 gpm limit, the SG tubing will thereby maintain adequate leakage integrity under these conditions.

4.5 Radiological Consequences

In its letter dated August 1, 1994, including Attachment H (WCAP-14046, Revision 1), the licensee provided the results of its calculation of the maximum allowable primary-to-secondary SG leakage during a postulated MSLB. This calculation was based on keeping the radiation exposure at the exclusion area boundary (EAB) below a small fraction of the guideline values in 10 CFR Part 100. The licensee's evaluation considered both the pre-accident iodine spike case and an event-generated iodine spike case. In its evaluation, the licensee calculated doses to the thyroid at the site boundary and concluded that the event-generated spike case is limiting. The licensee also concluded that the acceptance criteria for a postulated MSLB with an event-generated iodine spike, would be satisfied for a projected post-MSLB primary-to-secondary leak rate of 12.5 gpm in the faulted SG. The licensee then added 0.1 gpm from each of the other three SGs (i.e., the normal operational leakage) to obtain the maximum permissible leakage of 12.8 gpm from all four SGs. This value was derived by the licensee based on keeping the radiation exposure to a small fraction of the guideline values in 10 CFR Part 100. This maximum value of post-MSLB primary-to-secondary leakage further assumes a maximum allowable TS value of dose equivalent iodine-131 of 1.0 microcuries per gram of coolant.

The staff notes that the licensee's value for the maximum permissible SG leakage rate of 12.8 gpm at any time in the forthcoming operating cycle, was derived solely from consideration of radiation exposures. As such, it does not represent the SG leakage which will be determined based on the SG tube inspection conducted during the present refueling outage. This estimate of SG leakage will be submitted in accordance with the 90-day reporting requirements for voltage-based repair criteria.

The staff, in performing its evaluation of this event, has independently calculated the radiological consequences of a postulated MSLB at the EAB. The licensing basis value for χ/Q of 6.8×10^{-4} sec/m^3 was used in this calculation. The staff also used the dose conversion factors for iodine

isotopes set forth in ICRP 30 as well as the breathing rates set forth in RG 1.4. Table 1 presents the thyroid doses calculated by the staff for both the pre-accident spike case and the event-generated spike case using the licensee's value for the post-MSLB primary-to-secondary leak rate of 12.8 gpm from all four SGs.

TABLE 1

(12.8 gpm Primary-to-Secondary Leak Rate)

Calculation type and acceptance criteria	Thyroid dose (rem) pre-accident spike case	Thyroid dose (rem) event-generated iodine spike
EAB (2 hour)	85	12.1
Acceptance criteria	300	30

As can be seen from Table 1, the staff's calculated thyroid doses at the EAB, using the licensee's value of 12.8 gpm for the maximum permissible SG leakage at any time, are within the exposure guideline values of 10 CFR 100 for the pre-accident iodine spike case, thereby satisfying the acceptance criteria of SRP 15.1.5, Appendix A, "Radiological Consequences of Main Steam Line Failures Outside Containment of a PWR." Similarly, the staff's calculated thyroid dose for the event-generated spike case are a small fraction of the exposure guideline values of 10 CFR Part 100, thereby satisfying this acceptance criteria.

Based on the foregoing considerations, the staff concludes that the radiological consequences outside containment for a postulated MSLB for Byron 1, are acceptable, based on a calculated post-MSLB primary-to-secondary SG leakage rate not exceeding 12.8 gpm at any time in the forthcoming operating cycle.

4.6 Risk Based Evaluation

The licensee submitted in its letter dated October 17, 1994, a partial summary of the results of the Byron 1 SG inspection conducted during the current refueling outage. The data submitted included: (1) the distribution of eddy current indications of SG tube flaws in the TSP regions; and (2) the licensee's estimated conditional probability of rupturing one or more SG tubes, given depressurization of the secondary side by a postulated large steam or feed line break and assuming no structural constraint of the SG tube rupture by the TSPs.

The staff's initial evaluation of this information is that the risk at Byron 1, primarily associated with SGs "A" and "C," is bounded by our prior evaluation of the risk associated with single and multiple induced SG tube

ruptures for Braidwood 1 SG "D." This evaluation is in the safety evaluation issued in conjunction with Amendment No. 54 to the Braidwood 1 operating license on August 18, 1994. Specifically, ComEd calculated a conditional tube burst probability of 9×10^{-2} at EOC for Braidwood 1 for its present operating cycle. The staff found that this level of risk was acceptable for Braidwood 1 in light of its requirement that Braidwood 1 conduct a mid-cycle SG inspection.

Accordingly, the staff's conclusion is that operation of Byron 1 over the forthcoming operating cycle will not result in an unacceptable risk, based on this risk being bound by our previous evaluation for Braidwood 1. A key assumption in this conclusion is that flaw growth rates will not exceed the growth rates experienced in the last operating cycle (i.e., Operating Cycle 6). However, the staff notes that the flaw growth rates during Operating Cycle 6 significantly exceeded those occurring in Cycle 5. Therefore, the staff believes it is appropriate to conduct a mid-cycle SG inspection to ensure that flaw growth does not exceed accepted levels. This mid-cycle inspection will thereby provide assurance that the staff's assessment of the conditional core damage frequency is not being exceeded.

4.7 Leakage Monitoring and other Administrative Controls

In Attachment D of its letter dated August 1, 1994, the licensee provided a description of the system operational measures it would implement to provide for monitoring of and to respond to, SG tube leakage. These measures include the implementation of improved procedures and training of operators. These system operational measures are similar to those reviewed and found acceptable in License Amendment No. 54 issued on August 18, 1994, for Braidwood, Unit 1, which is a facility very similar to Byron, Unit 1, including the installation of the same model Westinghouse SG (i.e., Model D4). On this basis, we find these system operational measures acceptable. The staff is including its evaluation of these measures, referred to as safety enhancements in the Braidwood 1 safety evaluation, in this Byron 1 safety evaluation.

These safety enhancements include:

1. Lowering the alert and alarm setpoints on the main steam line and steam jet air ejector radiation monitors in both Units 1 and 2;

2. Making procedural changes to facilitate "quick counts" of chemistry samples to give rapid confirmation of SG leakage;

3. Increasing the chemistry sampling frequency to hourly when primary-to-secondary SG leakage is detected and then reducing the frequency to not less than daily when the SG leakage stabilizes;

4. Revising monitoring procedures to call for an hourly review of radiation monitor readings when SG leakage is detected;

5. Revising procedures to include the use of radiation monitor indications in the control room and the use of portable N-16 monitors to help ascertain SG leakage trends;

6. Upgrading training scenarios involving SG tube failures to include plant response data from an actual SG tube leak;

7. Revising SG leakage response procedures to better control and process contaminated secondary water resulting from a SG leakage event;

8. Verifying that steps in appropriate plant procedures continuously check for SG tube failure indications and do not use a "snap-shot" approach;

9. Revising control room surveillances to require that hourly trend readings of steam jet air ejector radiation monitor activity levels be reviewed on a daily basis.

Consistent with the voltage-based repair criteria approach discussed in draft NUREG-1477, the licensee has proposed to incorporate the 150 gpd primary-to-secondary leakage limit in the Byron Station TSs. The licensee also added administrative SG leak trend limits to its procedures. Presently, this limit is administratively enforced. With these administrative trend limits, plant shutdown is required in a 5-hour period if detectable leakage increases by 25 gpd per hour or more. For an increase above 100 gpd within one hour, plant shutdown is required in 4 hours. The 150 gpd leakage limit furnishes reasonable assurance that should a SG tube leak develop, it can be readily detected and the plant will be shut down before a tube rupture occurs. The 150 gpd value also provides for detection of SG leakage from a crack associated with the longest permissible freespan crack length. As discussed in the Westinghouse Report, WCAP-14046, Revision 1, the 150 gpd leakage corresponds to the leakage resulting from a 0.4 inch crack at nominal leak rates and a 0.6 inch long crack at 95 percent confidence level leak rates. This provides for plant shutdown prior to reaching critical crack lengths for postulated steam line break conditions at a SG leakage rate below the 95 percent confidence level and for the more restrictive three times normal operating pressure differential at less than nominal leak rates.

In summary, implementation of the above measures constitutes an acceptable defense-in-depth approach against tube failure and detection of flaws that would exceed steam line break leakage limits.

5.0 SUMMARY OF EVALUATION

5.1 Technical Summary

Based on the above evaluation, the staff concludes that adequate structural integrity of the SG tubing can be ensured for Cycle 7 at Byron, Unit 1, consistent with applicable regulatory requirements. In addition, the staff concludes that the methodology for determining the expected primary-to-secondary leakage during a postulated MSLB, assumed to occur at the

end of Cycle 7 for Byron, Unit 1, is acceptable. The staff's approval of the proposed voltage-based repair criteria is based on the licensee being able to demonstrate that the primary-to-secondary leakage during a postulated MSLB, will be acceptable. In accordance with the amended TSs, this demonstration will be submitted within 90 days after restart from the current refueling outage. The staff further concludes that the reduced operational leakage limits to be incorporated into the Byron TSs provide added assurance of SG tube structural and leakage integrity.

The staff notes that the licensee's letter dated October 17, 1994, presents inspection findings which indicate that several bobbin indications had voltages greater than expected. In addition, a few of these indications had voltages greater than that corresponding to the structural limit (i.e., above 4.5 volts) indicating that, at the end of the last operating cycle, some of these indications may not have been able to provide the full structural load capability discussed in the guidelines in RG 1.121.

The licensee also calculated the probability of SG tube burst under MSLB conditions based on the projected EOC voltage distribution; this information was included in its letter dated October 17, 1994. This analysis is still under staff review. The conditional probability of a SG tube rupture ranges 1.5×10^{-2} at BOC to a projected value of 3.3×10^{-2} at EOC. By limiting operation of Byron 1 during the forthcoming fuel cycle to mid-September 1995, the estimated conditional probability of SG tube rupture will be about 2.5×10^{-2}, which is comparable to the value used in NUREG-0844 for all SG tube degradation mechanisms. Further, the staff finds that this conditional probability of tube burst at EOC is bounded by the value of SG tube burst probability of Braidwood 1 during its present operating cycle and which we found acceptable. (Refer to Section 4.6 of this evaluation.)

Although the conservatisms of the assessment of the deterministic SG tube structural integrity are not quantified, nor are the contributions to the margin of safety from the leakage monitoring enhancements, the staff believes that these considerations provide reasonable assurance of an adequate margin of safety for the SG tubes to withstand the effects of a postulated MSLB. Further, the staff expects that the safety enhancements instituted by the licensee provide assurance that in the event there is a SG tube rupture, the plant operators can mitigate the effects and bring the plant safely to cold shutdown. The staff has also found that the risk of continued operation of Byron 1 to EOC during the forthcoming operating cycle is acceptable. However, the staff has also found that a mid-cycle SG inspection is warranted to determine whether the relatively large voltage growths measured during the last operating cycle are continuing. The licensee has committed in its letter dated October 24, 1994, to perform a mid-cycle SG tube inspection no later than September 15, 1995.

5.2 Approval of Technical Specification Revisions

The proposed changes to TS Section 4.4.5.2 are acceptable in that they incorporate into the TS surveillance requirements for the steam generators,

important elements related to the inspection guidelines for implementing the voltage-based repair criteria as proposed by the staff in its draft generic letter on this issue which was published in the Federal Register on August 12, 1994. Furthermore, the addition of TS Section 4.4.5.2.d limits, in part, the application of this voltage-based repair criteria to one cycle to allow the staff the opportunity to readily revise requirements regarding voltage-based repair criteria in light of additional information. Any such revisions would be initiated by: (1) public comments on the draft generic letter cited above; (2) operating experience at domestic nuclear power plants implementing this voltage-based repair criteria; and (3) European operating experience with voltage-based repair criteria. Similarly, the proposed changes to TS Section 4.4.5.4 are acceptable in that they incorporate important elements of the voltage-based repair criteria, as contained in the draft generic letter, into the acceptance criteria for inspecting steam generators. This includes for the first time, a formulation for leaving in service, certain measured steam generator tube bobbin voltages at tube support plate intersections in the event of an unscheduled inspection. (Refer to TS Section 4.4.5.4.a.11.e). The addition of this formulation is acceptable in that it is a conservative approach taken from the draft generic letter cited above. It also tends to reduce plugging of steam generator tubes, potentially reducing the rated power capacity of the plant without an offsetting increase in safety.

Finally, the proposed change to TS Section 4.4.5.5 is acceptable in that it establishes reporting requirements for prompt notification of the NRC staff by the licensee (i.e., prior to restart from a steam generator inspection outage) of any condition found during this inspection which could potentially invalidate the usage of the voltage-based repair criteria. This particular reporting requirement provides assurance that the voltage-based repair criteria will not be inappropriately applied for an operating plant. The 90-day reporting requirement for submitting the final results of the steam generator inspection and the tube integrity evaluation is also acceptable in that the staff will be notified of potentially unsafe steam generator conditions attributable to ODSCC degradation, in advance of its occurrence. The addition to Bases Section 3/4.4.5 is acceptable in that a leakage limit of 12.8 gallons per minute from all four steam generators, under the most limiting accident conditions, will not result in radiation exposures that exceed a small fraction of the guideline values in 10 CFR Part 100. This has been independently verified by the staff.

Based on the foregoing evaluation, the staff finds the proposed TS changes acceptable.

6.0 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.

We note here that in its letter dated September 12, 1994, the Department of Nuclear Safety, State of Illinois, provided the NRC its comments on the draft

generic letter published in the Federal Register on August 12, 1994, related to the voltage-based repair criteria for outer diameter stress corrosion cracking (ODSCC). While the State of Illinois indicated in its letter that it was pleased in general with the draft generic letter, it had two specific comments regarding its content. The staff presently plans to document its final position on the subject of ODSCC in a generic letter after considering public comments as well as domestic and European operating experience as discussed in Section 2.0. Inasmuch as the staff will address the specific comments of the State of Illinois when it prepares its final position on the inspection and repair of ODSCC, the staff did not include a review of these two specific comments on ODSCC in this evaluation.

7.0 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 and change surveillance requirements. 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 (59 FR 48917). 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.

8.0 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.

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