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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 77 TO FACILITY OPERATING LICENSE NO. NPF-37,

AMENDMENT NO. 77 TO FACILITY OPERATING LICENSE NO. NPF-66,

AMENDMENT NO. 69 TO FACILITY OPERATING LICENSE NO. NPF-72,

AND AMENDMENT NO. 69 TO FACILITY OPERATING LICENSE NO. NPF-77

COMMONWEALTH EDISON COMPANY

BYRON STATION, UNITS 1 AND 2

BRAIDWOOD STATION, UNITS 1 AND 2

DOCKET NOS. STN 50-454, STN 50-455, STN 50-456 AND STN 50-457

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1.0 INTRODUCTION

The Commonwealth Edison Company (ComEd, the licensee) submitted a request for license amendments and supporting technical documentation on September 1, 1995, to revise the Technical Specifications (TSs) for Byron and Braidwood Station, Units 1 and 2. The requested amendments, however, are only applicable to Units 1 of the Byron and Braidwood Stations. The licenses for Byron, Unit 2, and Braidwood, Unit 2, are being amended solely for the purpose of maintaining continuity in the license amendment numbers. The request for license amendments dated September 1, 1995, superseded the prior requests for license amendments dated February 13 and July 7, 1995, on this same matter. The additional submittals provided clarifying technical information that did not affect the initial No Significant Hazards Consideration published by the staff.

This request dated September 1, 1995, refers to prior and subsequent submittals dated January 28, February 7, March 15, March 20 (two letters), April 3, April 12, April 21, May 25, June 19, June 20, June 30, July 21 (two letters), July 28, July 31, August 14 (two letter), August 25 (two letters), September 1 (two letters), September 2, September 4, September 8, September 15, September 19, September 20, September 22, October 3, October 7, October 11 (two letters), October 13 (three letters), October 23 and October 26, 1995. The additional submittals provided clarifying technical information that did not affect the initial No Significant Hazards Consideration published by the staff.

The requested amendments modify, in part, the Byron, Unit 1, and Braidwood, Unit 1 TSs to permit on the hot-leg side of the steam generators (SGs), the use of a revised set of voltage-based SG tube repair criteria for a specific type of defect affecting the SG tubes. This defect does not extend outside the thickness of a tube support plate (TSP). All of the proposed changes to the SG tube repair criteria are applicable through Cycle 6 for Braidwood, Unit 1 and through Cycle 8 for Byron, Unit 1.

The NRC staff documented its generic position on voltage-based repair limits for outside diameter stress corrosion cracking (ODSCC) affecting the SG tubes at the TSP elevations in Generic Letter (GL) 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking" which was issued on August 3, 1995. The staff's position documented in GL 95-05 takes no credit for the TSPs preventing and/or reducing the likelihood of a SG tube from bursting and/or leaking during postulated accident conditions. In essence, it assumes that the degradation affecting the SG tubes at a TSP elevation is in the free span of the SG tube (i.e., between the TSPs). Hence, this approach is termed the free span model.

ComEd's proposal dated September 1, 1995, explicitly takes credit for the constraint provided by the TSPs in preventing and/or reducing the likelihood of SG tube burst and for reducing the amount of postulated accident leakage from SG tubes which attempt to burst, but are precluded from bursting by the constraint provided by the TSPs. This proposed approach is termed the locked TSP model. Although the current ComEd proposal (i.e., the locked TSP model) is different than the approach documented in GL 95-05 (i.e., the free span model), this proposal relies in part, and builds upon, the free span model documented in GL 95-05. Furthermore, both approaches are voltage-based; i.e., both rely on the voltage response from an eddy current inspection to assess the structural and leakage integrity of the SG tubing.

2.0 BACKGROUND

The current ComEd proposal addresses predominantly axially oriented ODSCC flaws which have been observed in the SG tubes at the TSP elevations. Since this current ComEd proposal takes credit for the constraint provided by the TSPs in reducing the likelihood of an axially oriented SG tube burst and in reducing the SG tube leakage during a postulated main steamline break (MSLB), the staff required ComEd to demonstrate that the TSPs continue to provide this constraint and that they do not move significantly during normal operating, transient, and postulated accident conditions such that this movement would expose a significant portion of the ODSCC flaw at the TSPs. To ensure the integrity of the TSPs and the SG internal structures that hold the TSPs in place, an inspection program of the key SG internal structures was developed and implemented by ComEd as described in Section 4.1 of this safety evaluation (SE).

With the as-built design of the SGs (i.e., without any internal structural modifications) and with no credit taken for deposits at the SG tube-to-TSP interface (i.e., the crevice region) restricting the motion of the TSPs during a postulated MSLB event, the potential displacements of the TSPs could be unacceptable in terms of reducing the likelihood of an axially oriented SG tube rupture and reducing potential SG tube leakage. As a result, the licensee has developed and proposed a mechanism to restrict the displacements of the TSPs. This method involves hydraulically expanding a number of SG tubes with sleeve stabilizers at key locations at the TSP elevations. In this process, bulges are created in the SG tube and its stabilizing sleeve, both above and below the TSPs, that are larger than the holes drilled in the TSPs. These bulges thereby provide a restraint on the movement of the TSPs during postulated accident conditions. The purpose of the sleeve installed at the expanded locations is to provide additional stabilization and additional stiffness at the expanded SG tube joints. The expanded SG tubes are then removed from service. The SG tube expansion process is discussed in detail in Section 4.2 of this SE.

Since ODSCC SG tube degradation is formed in the crevice regions between the SG tubes and the TSPs during normal operation, this degradation is confined within the thickness of the TSPs during normal operation. However, during transients and postulated accident conditions, the TSPs can move as a result of hydrodynamic loadings on the TSPs. The largest hydrodynamic loadings on the TSPs are imposed during an MSLB transient. Thermal-hydraulic codes, as discussed in Section 4.3 of this SE, were used to evaluate the parameters that affect the motion of the TSPs. The results of these thermal-hydraulic analyses were combined with other effects that determine the position of the TSPs relative to the SG tubes (e.g., differential expansion as a result of temperature changes within the SGs and bowing of the tubesheet). These combined effects formed the basis for evaluating the magnitude of the TSP displacements. The finite element structural analysis code used to calculate the TSP displacements is discussed in Section 4.4 of this SE.

The overall objective of the current ComEd proposal is to ensure that the predominantly axially oriented ODSCC indications in the SG tubes at the TSP elevations will retain adequate structural margin against burst as well as leakage integrity during the course of a limited operating interval. With minimal TSP displacements (i.e., less than 0.10-inches), predominantly axially oriented SG tube ODSCC indications at the TSP intersections will have a low likelihood of bursting axially since the very small diametral gap between the SG tubes and the TSPs constrains the SG tubes and prevents them from bursting axially. As a result, the SG tube voltage repair limit must be established so as to ensure a low likelihood of a SG tube failing as a result of axial tensile severing. In addition to this required structural analysis, an evaluation of the leakage from these SG tube ODSCC indications must also be performed. This SG tube leakage integrity analysis is necessary since through-wall or near through-wall flaws may be left in service as a result of this revised voltage-based repair criteria. The structural and leakage integrity analysis of the SG tubes is discussed in Section 4.5 of this SE.

To ensure that the primary-to-secondary leakage in the SGs under postulated accident conditions is acceptable, the radiological consequences as a result of this leakage must be evaluated. This evaluation is discussed in Section 4.6 of this SE.

Since the vast majority of the ODSCC indications at the TSP elevations in the Braidwood, Unit 1, and Byron, Unit 1, SGs have been observed on the hot-leg side of the SGs, the licensee has proposed to implement the locked TSP model at the hot-leg TSP elevations, subject to certain restrictions (e.g., dented locations). The licensee has also proposed to implement the free span model as documented in GL 95-05 at the cold-leg TSP elevations. SG tube indications at the flow distribution baffle plate, which has larger tube-to-baffle plate clearances than the TSPs above it, will be repaired in accordance with the existing depth-based repair criteria in the Byron and Braidwood TSs.

With this approach, predominantly axially oriented ODSCC indications in the SG tubes at the TSP elevations which do not extend outside the thickness of the TSPs, would be allowed to remain in service as follows:

(a) At all hot-leg TSP elevations (excluding the flow distribution baffle plates and TSP intersections that do not pass a 0.610-inch diameter probe, including the adjacent TSP intersections), all bobbin voltage indications less than or equal to 3.0 volts will be allowed to remain in service. Additionally, all bobbin voltage indications greater than 3.0 volts will be either plugged or repaired.

(b) At all cold-leg TSP elevations and for TSP intersections adjacent to TSP intersections that do not pass a 0.610-inch diameter probe, all bobbin voltage indications less than or equal to 1.0 volt, would be allowed to remain in service. Additionally, all bobbin voltage indications greater than 1.0 volt, but less than or equal to the upper voltage repair limit of GL 95-05 (i.e., about 2.7 volts), would be allowed to remain in service if a rotating pancake coil (RPC) probe, or equivalent, does not detect ODSCC degradation. Further, all bobbin voltage indications greater than the upper voltage repair limit of GL 95-05 and all bobbin voltage indications between 1.0 volt and the upper voltage repair limit of GL 95-05 which were confirmed with the RPC probe, or equivalent, to be flaw-like, would be either plugged or repaired.

The free span model has been previously approved for implementation at Braidwood, Unit 1, for one cycle only by License Amendment No. 54, issued on August 18, 1994. The free span model has also been approved for implementation at Byron, Unit 1, for one cycle only in License Amendment No. 66, issued on October 24, 1994.

3.0 PROPOSED STEAM GENERATOR TUBE REPAIR CRITERIA

Technical Specification 3.4.5, "Steam Generators," the bases for TS 3.4.5 and TS 3.4.8, "Specific Activity" are revised by the license amendments to specify the tube repair and leakage criteria for predominantly axially oriented ODSCC flaws confined within the thickness of the TSPs. The changes are only applicable through the forthcoming Cycle 6 at Braidwood, Unit 1, and through Cycle 8 at Byron, Unit 1 (i.e., the remainder of Cycle 7 and through all of Cycle 8). The proposed modifications to the SG tube repair and leakage criteria in the TSs are, for the most part, consistent with the model TSs contained in GL 95-05. However, there are some differences. These differences are primarily a result of implementing the locked TSP model at the hot-leg TSP intersections, excluding SG tube intersections adjacent to intersections which do not pass a 0.610-inch diameter probe and the free span model at the cold-leg TSP intersections, including those intersections adjacent to intersections SG tube which do not pass a 0.610-inch diameter probe. The repair criteria for the locked TSP model, specify, in part:

(a) SG tubes, with degradation attributed to ODSCC within the bounds of the hot-leg TSPs with a bobbin voltage less than or equal to 3.0 volts, will be allowed to remain in service.

(b) SG tubes with degradation attributed to ODSCC within the bounds of the hot-leg TSPs with a bobbin voltage greater than 3.0 volts, will be either repaired or plugged.

(c) If an unscheduled mid-cycle inspection is performed, the limits in Items (a) and (b) above apply rather than the mid-cycle equation in GL 95-05.

(d) If, following an inspection of the SG internal structures, indications detrimental to the integrity of the structural load path necessary to support the 3.0 volt interim plugging criteria (IPC) are found, the NRC will be notified by the licensee and an assessment of the safety significance of these indications will be provided by the licensee.

In addition to the TS changes cited above, the licensee also stated that for implementation of the proposed 3.0 volt repair criteria:

(a) All the applicable requirements contained in GL 95-05 will be implemented. The staff notes in this regard that the licensee is taking some exceptions to the guidance contained in GL 95-05. These exceptions are related to probe wear, RPC inspections, and the SG tube repair criteria developed in conjunction with locked TSP model.

(b) Prompt notification will be made to the staff by the licensee should corrosion-induced denting greater than 5.0 volts be found.

(c) A 0.610-inch diameter bobbin probe will be used as a go/no-go gauge to determine if the locked TSP model (i.e., the 3.0 volt criteria) can be applied to the TSP intersections and adjacent intersections. These latter intersections become involved if a 0.610-inch probe does not pass through a TSP intersection because it is assumed that denting has occurred. In this case, the free span model is applied to this SG tube intersection and the adjacent SG tube intersections.

(d) The integrity of the hot-leg TSPs will be verified by eddy current examination.

(e) Should any degradation of the structural load path within the SGs be found during an inspection of the SG internal structures, the NRC will be promptly notified of this degradation. A summary of the inspection results will be submitted to the NRC prior to entering Mode 4 and a complete inspection report will be submitted to the NRC within 90 days of plant startup. In addition, ComEd will notify the staff if any cracking is observed in the vertical bars or in the wedge welds, if any TSP cracking is detected, or if any stayrod or wrapper anomalies are identified.

In general, the licensee intends to follow the guidance of GL 95-05 with the exception of implementing the probe wear standard, RPC inspecting all intersections greater than 1.0 volt, and using the locked TSP model repair criteria for the hot-leg TSP elevations. The effect of this latter exception is to alter the lower repair limit, the SG tube leakage methodology, the probability of burst methodology, and the reporting requirements. These exceptions are discussed in Section 4.5.2 of this SE which specifically addresses the probe wear standard exception and the RPC inspection exception.

4.0 EVALUATION

4.1 Steam Generator Internals

4.1.1 Introduction

As discussed in Section 2.0, the constraint provided by the TSPs during normal operating, transient, and postulated accident conditions will be relied upon to some extent to ensure SG tube structural integrity for predominantly axially oriented ODSCC indications in the SG tubes at the hot-leg TSP elevations. As a result, the structural integrity of the TSPs and the SG internal structures which maintain the TSPs in position is necessary to provide reasonable assurance that the constraint provided by the TSPs for ODSCC flaws is maintained. The principal load path components supporting the TSPs are the tierods which are also referred to as stayrods, the vertical bars, the wedges, and the wrapper.

The majority of the tierods are threaded into the tubesheet and extend to the top TSP where a nut is threaded on the top of each tierod to hold the stack of TSPs in place. This nut is welded to the top TSP at two locations and to the tierod at one location. Between the TSPs and around each tierod are cylindrical spacers which extend from the top of one TSP to the bottom of the next higher TSP. There are eight spacers per typical tierod. The spacers are pipes surrounding the tierod which is a 1-inch diameter stud.

The vertical bars are positioned above and below the TSPs and are welded to the wrapper. Several pairs of vertical bars are located at various locations around each of the TSPs and the flow distribution baffle. Since the displacement of the TSPs under transient or postulated accident loads would be in a vertical direction, these loads on the TSPs would be reacted on either the vertical bars on the top or bottom of the TSPs. In a similar fashion, the wedges are located at various locations around the TSPs and are welded to the wrapper. The narrow end of the wedge is positioned downward relative to the TSPs and, hence, will only resist upward motion of the TSPs. The wrapper is supported by seven wrapper support blocks located around the circumference of the wrapper; these support blocks, in turn, are attached to the SG shell.

4.1.2 Integrity of Internals

ComEd has concluded that there is no basis to believe that the SG internal load path components which will restrict the displacements of the TSPs under loads have degraded as a result of operation unless SG tube denting has occurred. It is also the licensee's position that there will be no future degradation of these structural components. The licensee's conclusions are based, in part, on the following considerations:

(a) No load path component degradation has been observed in SGs fabricated by Westinghouse unless denting was present.

(b) No SG internal load path component degradation was observed during a secondary side SG tube removal conducted in the Braidwood, Unit 1, SG "C" in October 1993. This effort included a visual inspection of the top TSP, the vertical bars and the wedges above the top TSP.

(c) No differences between the design and as-built conditions were noted during the Braidwood, Unit 1, SG "C" visual inspection cited above.

(d) No operational mechanisms other than TSP corrosion-induced SG tube denting have been identified which would degrade the SG internal load path components. Further, Braidwood, Unit 1, and Byron, Unit 1, have not experienced corrosion-induced SG tube denting at the TSPs.

(e) ComEd concluded upon review of the fabrication records for the Braidwood, Unit 1, and Byron, Unit 1, SGs, that the load path components were installed in accordance with the design of these SGs.

(f) A survey by ComEd of other utilities regarding the issue of the integrity of the SG internal load path components has not identified any degradation other than that associated with corrosion-induced SG tube denting at the TSP intersections.

(g) Wrapper misalignment has not been observed at either Braidwood, Unit 1, or Byron, Unit 1, as demonstrated by the ability to insert the sludge lancing tool.

(h) Foreign experience with degradation of the SG internal load path components has been included in this ComEd evaluation.

(i) The corrosion behavior of carbon steel components in a low oxygen, high pH environment is well understood. Since the operating conditions in the Braidwood, Unit 1, and Byron, Unit 1, SGs (i.e., low oxygen concentrations and high pH) is not conducive to stress corrosion cracking of the carbon steel TSPs, there is no basis to expect corrosion of the SG internal load path components which are not subject to heat transfer mechanisms.

As discussed above, corrosion-induced denting can result in degradation of certain load path components (i.e., the TSP ligaments). For example, SG tube denting can result in cracking of the ligaments between TSP holes as has been observed at plants with a majority of the TSP intersections dented (i.e., with more than 50 percent of the TSP intersections dented). This type of TSP ligament cracking is a particular concern in this instance since it could adversely affect the TSP displacement analyses. ComEd has concluded, based on eddy current testing of the SG tubes, that TSP corrosion-induced SG tube denting has not occurred in either the Byron, Unit 1, or Braidwood, Unit 1, SGs. Nonetheless, the licensee has proposed to use a 0.610-inch diameter bobbin coil probe as a go/no-go gauge to monitor and assess the hot-leg TSP intersections to determine if denting were developing in the Byron, Unit 1, and Braidwood, Unit 1, SGs. A 0.610-inch diameter bobbin coil probe size was chosen based on an analysis by ComEd which indicates that a 65 mil diametral dent is necessary to induce a stress intensity which exceeds the yield strength of a TSP ligament. Since the SG tube inside diameter is nominally 0.664-inches, a 65 mil dent would result in an inside diameter of approximately 0.599-inch. Dents which are less than 65 mils are not expected to produce stress levels which would result in TSP ligament cracking.

To ensure that its assessments are correct with respect to the structural integrity of the SG internal load path components, ComEd developed an inspection plan for these components to provide further assurance of their integrity (i.e., a defense-in-depth measure). This inspection plan is discussed below in Section 4.1.3 of this SE.

4.1.3 Inspection Plan

The licensee has proposed an inspection plan intended to provide reasonable assurance that the SG internal load path components which will limit the displacements of the TSPs under transient and postulated accident loads, are not significantly degraded. In addition, the licensee has proposed an inspection plan to address the integrity of the TSPs. This inspection plan includes performing an audit inspection of each type of load path component, including the TSPs, to demonstrate that gross degradation of these components had not occurred. In addition, ComEd's inspection plan addressed the types of SG internal structural component degradation observed in foreign nuclear power plants.

For the present Braidwood, Unit 1, outage which started in September 1995, the licensee proposed the following inspection program for SG 1A:

(a) A visual examination of portions of the top TSP.

(b) An audit visual examination of a sample of the tierod nuts and spacers (i.e., about nine nuts and seven spacers).

(c) A visual verification of the wrapper alignment with respect to the SG shell.

(d) An audit visual inspection of a selected number of vertical bars (i.e., about 109) and their welds along the entire weld length. About 24 of these components were mechanically cleaned prior to the visual inspection. The remainder were flushed clean.

(e) A visual inspection of the wedges was performed on the top TSP. The entire weld length of these wedges was examined.

(f) A visual and eddy current inspection of the patch plate area of the top TSP. The patch plate is a region of the TSP where the plate was cut and subsequently reattached during the fabrication process.

The staff notes that the items cited in Section 4.1.2 above are intended by the licensee to provide assurance of the integrity of the SG internal load path components. The staff concludes that the inspections described in Section 4.1.3 are essential in providing reasonable assurance of the structural integrity of the SG internal load path components at Braidwood, Unit 1, and Byron, Unit 1, given the limited amount of inspection of these components which is possible. Although these inspections are concentrated in only one SG at Braidwood, Unit 1, the staff concludes that the inspections performed in this SG together with the eddy current inspections to be performed in all the SGs, provide reasonable assurance of the structural integrity of the internal load path components in all the SGs at Braidwood, Unit 1, through Cycle 6 and at Byron, Unit 1, through Cycle 8.

The staff's conclusion, however, on the structural integrity of the SG internal load path components is contingent upon satisfactory inspection findings. To this end, the licensee has committed to report to the NRC if any degradation is observed in the SG internal load path components, including their welds, and if any degradation is observed in the TSPs. The staff notes that for long-term implementation of a locked TSP model (i.e., a 3.0 volt repair criterion), it will be necessary to develop a plan designed to address the long-term integrity of these components. For this reason, the staff is limiting the applicability of the locked TSP model to one full operating cycle at Byron, Unit 1, and Braidwood, Unit 1, as cited above.

4.2 Steam Generator Tube Expansion

To maintain acceptably low, the probability that a SG tube fails axially due to axial cracks at the TSP intersections, the licensee has proposed to take credit for the constraining effects offered by the TSPs on SG tube ODSCC flaws. To this end, the licensee has proposed to limit the motion of the TSP during transient and postulated accident conditions by hydraulically expanding selected SG tubes at a number of TSP intersections. This will be done only at hot-leg TSP intersections since the free span model of GL 95-05, which does not take credit for the constraining effect of the TSPs, will be applied to the cold-leg TSP intersections. The tubes which are expanded at the hot-leg TSP intersections will function as additional stayrods, thereby restricting TSP displacements under transient and postulated accident conditions. The SG tubes selected for expansion are based on the analyses discussed in Sections 4.3 and 4.4 of this SE.

As discussed above, the licensee has proposed to expand selected SG tubes to limit the SG tube motion relative to the TSPs during a postulated MSLB event, thereby resulting in negligible axial tube burst probabilities of ODSCC flaws. The SG tube expansion process discussed above converts a limited number of SG tubes (i.e., 21 SG tubes in each of the four SGs at each unit) into stayrods. The licensee intends to accomplish this process by hydraulically expanding several SG tubes with sleeve stabilizers at key locations at a number of TSP elevations. During this process, bulges are created both above and below the TSP which are larger than the holes drilled in the TSPs. These bulges provide additional restraint on the TSP motion during postulated accident conditions.

The sleeve stabilizer is expanded with the parent SG tube and thereby: (1) increases the expansion stiffness at a given diametral expansion; and (2) prevents lateral motion or adjacent tube damage for a postulated severed SG expansion joint. The added stiffness of the expanded SG joints at the TSP intersections due to the sleeve stabilizer provides additional resistance to TSP displacement under various TSP loading conditions. The inspections to be performed on the expanded SG tubes are discussed in Section 4.5.2 of this SE. The expanded SG tubes are removed from service by plugging after the expansion process and its associated inspections have been completed.

4.3 Hydrodynamic Loads on the Tube Support Plates

4.3.1 Introduction

One of the objectives of the staff's review is to determine the acceptability of the hydrodynamic loads calculated by the licensee. The original calculations of these loads by the licensee were performed using the Westinghouse code, TRANFLO. This code has been previously accepted by the staff for evaluating mass and energy release into a reactor primary containment in the event of an MSLB, but not for detailed modeling of internal thermal-hydraulic conditions in a SG resulting from blowdown transients. Subsequently, the licensee elected to base its calculations of the hydrodynamic loads on the TSPs using RELAP5/MOD3 rather than TRANFLO. The staff evaluation of this revised submittal based on the use of RELAP5/MOD3, is provided below.

4.3.2 Main Steamline Blowdown Conditions

The staff's review of the licensee's methodology is partially based on the transient effects observed in tests cited by the licensee and widely available known results from other vessel blowdown tests. The licensee's submittals described the thermal-hydraulic conditions which would occur during the initial period of an MSLB transient (i.e., when peak SG internal loads occur). The discussion in WCAP-14273 stated that: (1) the differential pressure across the TSPs resulting from an MSLB at hot standby is the limiting case; (2) a flow split is expected in the SG tube bundle; (3) the timing of the peak differential pressure on the TSPs was associated with a change in the SG break flow quality; and (4) a significant acoustic component of the loads on the TSPs was not expected.

The licensee's descriptions of thermal-hydraulic conditions in the SGs are reasonable and account for the major effects contributing to the hydrodynamic loads on the TSPs. However, the magnitudes and relative contributions of these effects are not clearly understood. Specifically, some of the expected phenomena, such as flashing, level swell and liquid entrainment, were observed in scaled model tests of SGs. Other phenomena, notably the predicted flow split, were not. Hence, the ability of a computer code to predict TSP loads due to transient effects needs to be evaluated by comparison to blowdown conditions observed in tests. To this end, the licensee performed a comparison of SG tube bundle differential pressure data from steamline break (SLB) blowdown tests as described in the following sections.

4.3.3 Licensee Calculations

In its letter dated October 12, 1995, the licensee submitted results of its RELAP5/MOD3 calculations as the basis for its analysis of TSP hydrodynamic loads. The licensee's justification for using RELAP5 for these calculations was based on extensive testing of this particular computer code for a variety of applications, including separate effects tests, and integral test conditions. Additionally, RELAP5/MOD3 has been used to simulate vessel blowdown tests and bundle boiloff tests and which are documented in the RELAP5/MOD3 Code Manual. These tests show that the critical flow model in this code and its ability to predict overall voiding conditions, are applicable to blowdown conditions. The licensee also presented information showing this code's capability to predict the axial profile of void fraction in blowdown tests. The licensee stated that RELAP5/MOD3 over predicts void fraction in the boiloff tests. This preceding information cited by the licensee indicates that the wide range of specific applications allowed by prior qualifications of RELAP5 provides a measure of confidence that RELAP5 can be used to predict transient blowdown conditions in the Byron, Unit 1, and Braidwood, Unit 1, SGs.

The noding scheme used by the licensee in its RELAP5/MOD3 model used very short axial nodes on either side of the TSPs which in turn were immediately adjacent to much larger axial nodes. The volumes of the nodes directly adjacent to the TSPs represented about 6 cubic feet in the SGs whereas adjoining axial nodes ranged in volume from about 190 to 450 cubic feet. However, Section 3.2.1 of the RELAP5/MOD3 Code Manual recommends that the volumes of adjacent cells not differ by more than an order of magnitude. Accordingly, the licensee performed nodalization studies with its RELAP5 model to show that this deviation from the guidance in the RELAP5 manual did not significantly affect the results of its calculations.

The licensee's RELAP5/MOD3 calculations used a two phase (i.e., water and steam) non-equilibrium approach which yielded apparently non-realistic results in terms of physical phenomena (i.e., very sharp pressure peaks). Accordingly, the licensee chose to modify the RELAP5 model by assuming thermal equilibrium between the two fluid phases in the SG tube bundle, but maintained separate flow characteristics for each phase.

The licensee attempted to determine the source of the unstable behavior found when using RELAP5/MOD3 without the thermal equilibrium assumption discussed above. The licensee found that the calculation of the interfacial heat transfer based on a model in RELAP5/MOD3, does not appear to be accurate. (This was confirmed by the code's developer.) This effect was demonstrated in assessment problems evaluated by the licensee which compared RELAP5/MOD3 with RELAP5/MOD1 and MOD2 results. In these assessment problems, MOD3 of the code displayed unstable characteristics similar to those seen in TSP loads calculated using a nonequilibrium assumption, while the earlier RELAP5 versions performed more reliably.

The licensee performed a set of sensitivity studies using the RELAP5/MOD3 representation of the Westinghouse Model D4 SG, assuming thermal equilibrium between fluid phases. Variations were introduced in the separator performance, the TSP loss coefficients, the initial SG water levels, the break flow, the node lengths at the TSPs, and the size of the calculational time step. These studies showed that the RELAP5 model was relatively insensitive to: (1) changes in separator performance since the separators are predicted to be flooded during level swell; (2) the node sizes at the TSPs; and (3) the length of the time step. As expected, the results were sensitive to calculations using altered break flows, altered TSP loss coefficients, and lower water levels. The TSP loads changed by as much as 26 percent when assuming a 20 percent increase in the break flow, and a 27 percent change was found when the initial water level was almost 100 inches below the normal, hot standby level. These studies showed that the basic RELAP5 model was stable and that it behaved predictably when using modified input parameters (i.e., assuming thermal equilibrium between fluid phases).

To substantiate the assumptions used in its modeling of the Byron, Unit 1, and Braidwood, Unit 1, SGs, the licensee conducted a RELAP5/MOD3 simulation of a SG blowdown conducted in the MB-2 steamline break tests described in NUREG/CR-4751, dated October 1986. The licensee used a detailed TSP noding scheme similar to that used to model the Byron, Unit 1, and Braidwood, Unit 1, SGs, and assumed both a nonequilibrium condition and an equilibrium condition in the SG tube bundle between the two phases, similar to that which was done for the Byron, Unit 1, and Braidwood, Unit 1, SGs. The test data in the MB-2 tests were taken at 0.10 second intervals, thereby introducing some uncertainty regarding the maximum pressure measured (i.e., the actual maximum may have occurred between recorded data points). Nevertheless, the results of the calculation when assuming nonequilibrium conditions between the two phases, diverged significantly from the MB-2 test data, not only in the magnitude of the predicted differential pressure across the TSPs, but also in the time when the peak loads occurred in the MB-2 tests. Alternatively, the predictions of TSP loads assuming thermal equilibrium between phases followed the general trend of the MB-2 test data, but overpredicted the differential pressures. The RELAP5/MOD3 code performed better at the upper TSPs, the locations of maximum loads, than it did at the lower TSPs. Overall, the case assuming thermal equilibrium in the calculation of the MB-2 steamline break test data provided a reasonable comparison with the maximum loads observed in the tests, thereby providing assurance that the approach proposed by the licensee in using RELAP5/MOD3 with the assumption of thermal equilibrium between the two phases, is reasonable for calculating the blowdown loads inside the Byron, Unit 1, and Braidwood, Unit 1, SGs.

The licensee calculated TSP loads for the Byron, Unit 1, and Braidwood, Unit 1, SGs were limited to one set of plant conditions (i.e., a postulated MSLB from hot standby conditions). The licensee also performed calculations at each TSP to confirm the Westinghouse conclusion that the peak loads would occur on the uppermost TSP.

4.3.4 Audit Calculations and Comparisons

The staff obtained modeling information from the licensee so as to perform an independent audit evaluation of the TSP loading calculations for the hot standby MSLB case. The staff used RELAP5/MOD3.1.1.1, basing its model on a representation of the Westinghouse Model D4 SG discussed in WCAP-14273. The staff also performed an audit calculation using the TRAC-PF1/MOD2 code to understand the basis for the apparently unstable results found when using RELAP5/MOD3. The TRAC results are similar to those obtained by the licensee when using RELAP5/MOD3 and assuming thermal equilibrium between phases. The maximum differential pressures were comparable and the apparent instability observed in some of RELAP5/MOD3 calculations, was not found in the TRAC results. The temperature difference between steam and water phases inside the SG model predicted in the TRAC calculation was less than a degree celsius, thereby supporting the reasonableness of the thermal equilibrium assumption for RELAP5/MOD3 calculations.

The staff notes that the licensee increased the loads used in the structural analysis of the TSPs by adding 50 percent to the loads calculated using RELAP5/MOD3. This increase is greater than any of the changes to TSP loads seen in the licensee's sensitivity analyses. The staff concludes that the licensee has selected the limiting condition (i.e., hot standby) for an MSLB event since MB-2 tests show that the TSP loads should be higher for an MSLB event occurring from hot standby than if it occurred from full power conditions.

4.3.5 Conclusions Regarding the Hydrodynamic Load Calculations

The staff reviewed the licensee's thermal-hydraulic model, performed independent audit calculations, and reviewed data from applicable tests. Based on this review, the staff concludes that the TSP hydrodynamic loads proposed by the licensee are acceptable for analysis of the TSP deflections. The hydrodynamic loads calculated by the licensee assuming equilibrium heat transfer conditions in the SG tube bundle, result in peak loads across the TSPs which the staff finds to be reasonable estimates of conditions resulting from a postulated MSLB. This finding is based on a comparison of the predictions of differential pressures across the TSPs using RELAP5/MOD3 with the values measured in the MB-2 tests. Additionally, the staff audit calculations performed using both RELAP5/MOD3 and TRAC-PF1/MOD2 yielded results comparable to those obtained by the licensee. However, the conclusions of this review do not constitute approval of RELAP5/MOD3 as a generically applicable method of predicting TSP hydrodynamic loads. On this basis, the staff finds that the licensee's proposed values of the differential pressures across the TSPs are acceptable.

The staff notes that its review of the suitability of the TRANFLO code for this application showed that more complete TRANFLO code documentation and validation are needed before the staff could accept the use of TRANFLO to predict SG internal hydrodynamic loads on the SG TSPs in the event of an MSLB.

4.4 Steam Generator Tube Support Plate Displacements

4.4.1 Introduction

The structural analysis of the displacements of the TSPs under the hydrodynamic loads evaluated in Section 4.3 of this SE involves the computer modeling of the hot-leg side of the SG tube bundle of the Westinghouse Model D4 SGs. The major structural components of this SG include the flow distribution baffle (FDB) plate, seven TSPs, tie rods and spacers, a channel head, a lower shell, a tubesheet, and vertical bars and wedges. The Westinghouse computer code WECAN, a general purpose finite element structural analysis code, was used by ComEd to model these structural components. The structural model is composed mainly of shell elements, with beam elements used to simulate the tierods and spacers. Calculations were performed to define applicable dynamic degrees of freedom (DOF) for each TSP. Once the DOF were defined, a global substructure was generated for the overall SG tube bundle. The displacement-time history of the TSPs was then calculated using the Westinghouse special purpose computer program, PLTDYM.

The component material properties are taken from the 1971 edition, through summer 1972 addenda, of the American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), which is the applicable code edition for Byron, Unit 1, and Braidwood, Unit 1.

4.4.2 Description of the Analytical Model Representing the Westinghouse Model D4 Steam Generator

The various TSPs and baffle plates are supported vertically within the SG using several support mechanisms. A schematic of the tube bundle region is shown in Figure 1, with each of the various plates identified. Westinghouse uses letter designations to identify the baffle plates at various elevations with 'A' representing the FDB and 'B,' 'D,' 'E,' 'G,' and 'H,' representing preheater baffle plates which have no circular holes. On the hot-leg side, two semi-circular plates, 'C,' and 'F,' with SG tube holes and circulation holes, are located at the elevations of the 'D' and 'G' preheater baffle plates. Plates J and K on the hot-leg and cold-leg side at the top of the preheater have SG tube holes and circulation holes. The remainder of the TSPs 'L,' 'M,' 'N,' and 'P' are full circular TSPs with similar SG tube and circulation holes. In addition, the 'L' and 'P' TSPs contain central flow slots along the SG tube lane to enhance flow upward through the SG tube bundle. For the Braidwood, Unit 1, and Byron, Unit 1, SGs, number designations are used for the TSPs. Counting upwards from the FDB plate through the preheater to the top TSP, the correspondence with the Westinghouse letter designations are: 1H = A, 2H = B, 3H = C, 4H = E, 5H = F and G, 6H = H, 7H = J and K, 8H = L, 9H = M, 10H = N and 11H = P. All of the TSPs are supported by three tierods and spacers in each of the TSP quadrants. In addition, TSPs C (3H), F (5H), and J (7H) (the Braidwood, Unit 1, and Byron, Unit 1, TSP numbers are in parentheses), in the preheater region are supported at their center by a vertical bar welded to the partition TSP, while the TSPs above the preheater, L (8H), M (9H), N (10H), and P (11H), are supported at the center by a central tierod and spacer. Additional support is also provided to the TSPs by vertical bars welded to the wrapper and/or partition TSP immediately above and below the TSPs.

The in-plane support for the TSPs is provided by wedges located around the circumference of each TSP. In all cases, these wedges are welded to the wrapper. However, since these wedges are inserted with their narrow dimension directed downward, they provide resistance only to upward vertical motion of the TSPs. When ComEd performed a preliminary set of structural calculations, it did not take credit for any vertical support provided by these wedges. However, the calculated displacements showed that for the limiting TSPs, the maximum displacements under MSLB loads occur near the SG tube lane at the outer edge of the TSP. Accordingly, in performing subsequent analyses, the support provided by these wedges was included at one location for the TSPs having the highest deflections in that area. When the hydrodynamic loads imposed by an MSLB are directed downward, the wedges at the corners of these TSPs do not provide vertical support with the result that the maximum downward TSP displacements occur at the corners along the SG tubelane. The tierods are bars which are threaded into the tubesheet and run the full height of the SG tube bundle and are secured by a nut on the upper side of the top TSP. Surrounding these tierods are cylindrical spacers (i.e., pipes) which are located between each of the TSPs. Since there is no structural connection between these spacers and the TSPs, this introduces a non-linear effect in the analysis of the internal SG structures. This non-linearity has been incorporated into ComEd's analytical model. In the upward direction, the load path is through the tierods, the spacers, or both, depending on the structural elongation of the tierods. Upward loads are carried from each TSP to the one above it, to the top TSP. For downward loads, the load path is through the spacers from each TSP to the one below it, down through the SG tube bundle to the tubesheet. In general, the downward load path is several times as stiff as the upward load path. As a result of the TSP deflections and rotations under MSLB loads, there is a potential for interaction between the TSPs and the SG tubes. These effects have also been incorporated into the licensee's analysis. If the TSPs rotate locally such that the top surface of a TSP contacts the SG tube on one side while the bottom surface of the TSP contacts the SG tube on the other side, this SG tube will bind in the TSP and resist further deflection of the TSP.

All of the structural components cited above, with the exception of the tierods, were modeled analytically using three-dimensional shell elements. The tierods were modeled using three-dimensional beam elements. The spacers were incorporated in the computer model by using appropriate stiffness factors which are coupled to the various TSP elements when the gaps between the spacers and the TSPs are closed under loading.

In modeling the TSPs, the various cutouts along the SG tubelane, the cutout for the FDB plates in the center of the hot-leg side, and the cutouts at the outer edges of TSPs N (10H) and P (11H), have been represented. In terms of the material properties of these components, equivalent properties are specified only in the tubed regions of a TSP (i.e., that portion with numerous circular holes for the SG tubes). Actual TSP properties were used along the SG tubelane and at the periphery of the TSPs.

However, the material properties for the tubesheet and TSPs were modified to account for the SG tube penetrations, flow holes, and various cutouts. The modified material properties are Young's modulus, Poisson's ratio, and the material density. In the case of the TSPs, their density was additionally modified to account for the added mass of the secondary side fluid.

Due to the presence of flow holes in the TSPs, but not in the FDB plate, separate formulations were used to modify the material properties. Although different formulations were used for these two separate structural components, the same methodology was used in each case. Due to the square penetration pattern of the some of the holes, different material properties were assigned in the pitch and diagonal directions. Equivalent parameters for Young's modulus and Poisson's ratio in the pitch and diagonal directions were also established. On the basis of its review of the licensee's modeling techniques, the staff finds that the analytical model representing the internal structural components of the SG is acceptable.

4.4.3 Stress Analysis Methodology

In determining the TSP displacements under the hydrodynamic loads imposed by a postulated MSLB, and then selecting the number and locations of the proposed SG tube expansions, the licensee first developed structural analysis models which did not include the effect of the SG tubes which would be expanded. This approach was necessary so as to make an efficient preliminary selection of the locations of the expanded SG tubes as indicated by the maximum TSP displacements without benefit of the SG tube expansions. This section of the SE addresses only the methodology developed by the licensee for the first step discussed above. Section 4.4.4 of the SE addresses the iterative process to establish the reference design locations of the expanded SG tubes.

The TSP analysis presented in WCAP-14273 was based on the use of TRANFLO to calculate the hydrodynamic loads. Based on its review of TRANFLO, the staff determined that RELAP5 is a more appropriate thermal-hydraulic code for evaluating the hydrodynamic loads occurring in a SG during a postulated MSLB. As a result, the licensee submitted an addendum to the Westinghouse report cited above which reflected the structural analysis of the TSPs using hydrodynamic loads calculated by RELAP5/MOD3.

The loads calculated by the thermal-hydraulic analyses discussed in Section 4.3 of this SE were used to calculate the displacements of the TSPs for the hot standby operating condition. The structural analysis computer codes, WECAN and PLTDYM, were used for this purpose. The WECAN code generates a finite element model representing the Model D4 SG, including the mass and stiffness matrices which are then input to the special purpose computer program, PLTDYM. The displacement-time histories were generated both by the PLTDYM and the WECAN codes. The staff has reviewed the WECAN code in previous applications and finds that its use for the current application is acceptable. The capabilities of the PLTDYM code allow the incorporation of the non-linear spacer support interactions and SG tube/TSP interactions. The SG tube/TSP interaction is modeled so that a single SG tube will pass up through each of the TSPs with the potential for interaction with more than one TSP. The staff has reviewed the documentation of the PLTDYM code and finds it acceptable for this analysis.

Using the displacement-time histories, the maximum TSP displacements and their corresponding times of maximum displacements are determined for each of the TSPs. TSP displacements are then calculated over an entire TSP diameter for the limiting TSPs at the critical times and superimposed on a SG tube map for local regions of the TSPs. Displacements are then calculated at each SG tube location within these local regions by interpolating between the displacements of the closest nodes in the analytical model. The number of SG tubes with a given displacement amplitude with respect to a TSP is then determined and provided as input to the SG tube burst analysis discussed in Section 4.5 of this SE. Since previous inspections of the TSPs indicate that there is little relative movement between the SG tubes and TSPs throughout an operating cycle, the relative movement of a SG tube with respect to a TSP are based on the SG tube and TSP positions assumed at the initiation of the MSLB transient.

The licensee also performed calculations to demonstrate the acceptability of an elastic analysis in determining the TSP displacements. These calculations showed that the tierods and spacers remain elastic throughout the postulated MSLB transient and that significant yielding of the TSPs will not occur. These calculations also indicate that the welds joining the vertical bars providing vertical restraint for the TSPs, remain structurally sound throughout the postulated transient.

The results of these structural analyses indicate that the limiting TSP displacement occurs when the MSLB is initiated from the hot standby condition and the MSLB break is postulated to occur close to the SG nozzle. The results of these analyses further show that the bottom TSPs experience the largest deflections. Additionally, the response of the TSPs under the transient loads is that once SG tube/TSP interaction occurs due to local TSP rotations, the SG tubes and the TSPs remain in contact throughout the remainder of the transient.

The bow of the tubesheet under the postulated MSLB displaces all SG tubes in an axial direction by the amount of the bow in the tubesheet while the TSP displacements closely match the bow of the tubesheet only at the locations of the tierods. The pressure differentials across the TSPs tend to displace the TSPs in an upward direction relative to the SG tubes at the time of peak displacements. The net displacement of any TSP is, therefore, the sum of the TSP displacements resulting from the tubesheet bow interaction through the tierods and that resulting from the pressure differential across the TSPs. Accordingly, the movement of a TSP relative to a SG tube is the difference between the net TSP displacements and the corresponding tubesheet bow. The net displacement of a TSP relative to an ODSCC flaw in a SG tube is the change in relative MSLB tube (or tubesheet) displacement at a given time during the MSLB and the start of the MSLB event.

Since the licensee's dynamic analysis is based on an elastic response, the licensee performed calculations to provide assurance that the tierods, a significant structural support element for the TSPs, remain elastic throughout the transient. The results of this dynamic analysis demonstrate that the tierods do, in fact, remain elastic throughout the MSLB transient. The maximum tensile stress in the tierods has been determined to be well below the yield point for the material. Similarly, for the spacers around the tierods, the maximum compressive stress is well below the yield stress of 23,400 psi.

The licensee also calculated the stresses in Plates A(1H), C(3H), and J(7H) for the limiting set of hydrodynamic loads. In order to properly interpret the stress results, stress contour plots for the maximum and minimum stress intensities were constructed for each of these plates. The maximum stresses in these plates occurred near the locations where there was vertical support (i.e., near the tierod/spacers and vertical bars). The results for Plate A show that the stresses are elastic throughout this plate. For Plates C(3H) and J(7H), there are local areas near the tierods, where the bending stresses slightly exceed the yield stress.

These calculated plate stresses in the equivalent solid plate can not be compared directly to the yield strength of the base material since these stresses are determined using an equivalent solid plate representing a plate with holes and cutouts. In order to accurately arrive at the actual plate ligament stresses, an additional detailed stress analysis of the TSPs would be required. Such an analysis is, however, not necessary since the equivalent solid plate stresses calculated by the licensee provide a general guideline to those areas of the plate which have the most limiting stresses. The equivalent plate stresses are meaningful in the sense that the calculated stresses using an equivalent solid plate have been shown by the licensee to be generally low throughout the plate, thereby demonstrating that the elastic analysis used by the licensee is a good approximation of the transient plate response. For plate C(3H), which experiences the highest stresses under MSLB loads, local yielding of the TSP near the tierods will not lead to a significant change in the maximum calculated displacements since they are limited by the SG tube/TSP interaction. Overall, the staff finds that the licensee has shown that its elastic analysis provides a good approximation of the dynamic response of the TSPs under the applied loading. On this basis, the staff finds that this elastic analysis is acceptable.

The licensee also performed structural calculations to determine the stresses in the welds between the vertical bars and the partition TSP and the wrapper. The loads at the various support points are extracted from the static WECAN runs in the form of reaction forces at the times of maximum TSP deflections. These loads were extracted by the licensee for the limiting TSPs based on TSP motions for the limiting set of MSLB loads. The licensee also performed calculations for the limiting TSP above the preheater, TSP P(11H), as this plate has a somewhat different support arrangement than the TSPs below it. Specifically, the vertical bars supporting this plate are welded to the partition TSP and/or the wrapper using a full length fillet weld along both edges of the vertical bar. A summary of the reaction forces and corresponding stresses for each of the vertical bars for the locations considered were provided by the licensee. The results of these calculations show that all of the stresses are low (i.e., less than 3000 psi) for the limiting MSLB. The staff finds that the stresses in these vertical bar welds are acceptable.

The licensee also performed a set of calculations for the bounding case MSLB to determine the stresses induced in the SG tubes as a result of the SG tube/TSP interaction. The results of these calculations indicate that the SG tubes remain elastic during the transient event. The licensee's analysis assumes contact with a single SG tube. However, it is likely that more than one SG tube would contact a TSP, thereby distributing the contact forces over a number of SG tubes which would have the net effect of reducing the TSP deflections and would thereby result in less exposure of the ODSCC flaws.

The staff finds the licensee's analytical approach, as discussed above, conservative and, therefore, acceptable.

4.4.4 TSP Displacements With the Implementation of the SG Tube Expansions

Using the calculated displacements for the case discussed above which did not take credit for the proposed SG tube expansions, the locations of highest displacement were identified as possible candidate locations for the SG tube expansion process. Incorporating the appropriate expanded SG tube stiffness into the dynamic analysis discussed above, a preliminary set of TSP displacements was obtained. The candidate expansion locations were then modified to either add more, or move some, to the new set of highest TSP displacements. This process was continued until all the TSP displacements were calculated to be less than a limiting value of 0.100 inches.

Stress solutions were then obtained for the limiting TSPs at various times in the dynamic analysis. For TSP P, the results of this stress analysis indicated that yielding of this TSP in the vicinity of the cutouts along the SG tube lane could potentially result in increased TSP displacements. Accordingly, a pinned connection was assumed for the critical stress locations, and a new dynamic solution was obtained. The results of this effort indicated that an additional tube expansion along the SG tube lane was necessary, and two final expansion locations (i.e., one on each side of the SG tube bundle) were added to the SG tube expansion matrix.

The effects of SG tube expansion are more significant for the lower TSPs which experience relatively large displacements at the corners of the TSPs (these TSPs do not have nearby SG tube expansions to provide structural support), than for the upper TSPs. The effect of the expanded SG tubes on the displacement of the upper TSP is due to the reduced stiffness of the expanded SG tubes for the upper TSPs as compared to the lower TSPs. This reduced stiffness, in turn, is due to the significantly large SG tube span between the tubesheet and the top TSP.

The licensee performed a set of calculations where the locations of the expanded SG tubes were shifted slightly from their reference design position (i.e., the SG tube expansion matrix). In general, the reference design locations of these expanded SG tubes were shifted by one node point in the finite element model away from the reference design position. The direction of the movement was based on a review of the results of the TSP displacement analysis to determine the most effective alternate positions for the expanded SG tubes.

Based on the results of the above calculations, the licensee made a determination of the number and location of the SG tube expansions. A range of SG tube expansion locations was defined for use in selecting the final SG tube expansion matrix for the Byron, Unit 1, and Braidwood, Unit 1, SGs. By establishing a range of SG tube expansion locations, the licensee was thereby able to select candidate locations which could reflect the results of the eddy current inspections of the candidate SG tubes.

The staff finds that the number and locations of the SG tubes identified for expansion is reasonable and, therefore, acceptable.

4.4.5 Redundant SG Tube Expansions for Postulated Circumferential Cracking

In order to provide redundancy at the most critical locations for SG tube expansions, a second SG tube was specified for expansion for TSPs C (3H) and F (5H) in the corner region of these plates, and for TSPs N (10H) and P (11H) in the central region of each of these TSPs. The addition of a redundant SG tube expansion at these locations is intended to provide added assurance of a structurally sound SG tube expansion in the unlikely event that a circumferential crack develops at a SG tube expansion joint with a subsequent loss of load carrying capability of the flawed expanded SG tube. The licensee submitted a summary of the resulting maximum TSP displacements, including the locations of the redundant tube expansions. We note, by comparing the TSP displacements for the reference design locations with the TSP displacements calculated with the redundant SG tubes, that these redundant SG tube expansions do not significantly reduce the values of the TSP displacements calculated for the reference design expansions. This is not unexpected in that the intent of these redundant SG tube expansions, is to provide redundancy only, and not a further reduction of the limiting TSP displacements.

Based on our review of the licensee's selection of redundant SG tube expansion locations, we find that the licensee's choice of these locations is acceptable.

4.4.6 Structural Effects of Expanded SG Tubes

The licensee evaluated the influence of the proposed SG tube expansions on the structural integrity of the SG tube bundle assembly and its attachments to the SG shell in light of two conditions that may exist: (1) the TSP tube crevices are open and the tubes move freely, except for normal contact friction, through the TSPs; and (2) the SG tubes are assumed to be locked into the TSPs as a result of packing of corrosion products in the TSP crevices and/or denting. The licensee showed that with the TSP crevices open, the expanded SG tubes function as an additional tierod and introduce no new significant loading conditions. With the SG tubes effectively locked at the TSPs, the expanded SG tubes are equivalent to another SG tierod. The licensee also performed calculations to determine the axial forces in the expanded SG tubes during a postulated MSLB. The maximum force in the expanded SG tubes for each of the expansion regions was calculated to be low (i.e., less than 500 pounds).

The SG tube lockup condition cited above (i.e., the second condition), causes interactions among the SG tubes, the TSPs, the wrapper, the wrapper support structure and the tubesheet due to thermal cycling in the SGs. During cooldown, interaction stresses occur due to differential thermal contraction between the SG tubes and the TSPs. Because the SG expanded tubes are locked into the TSPs, bending of the TSPs is induced and is a maximum at the top TSP, and incrementally smaller at each lower TSP. Further, since the TSPs are axially fixed to the tierods and the wrapper, the tierods and the wrapper react these thermally induced forces on the TSPs. Local bending of a TSP is expected at the tierod locations and at the wrapper backup bars. Since the SG tubes are anchored at the tubesheet, the net effect is to load the wrapper-to-shell support structure so as to react the wrapper loads while the tubesheet reacts the tierod forces.

Since the SG tube expansion process is implemented at cold shutdown conditions, the SG tubes which are locked to the TSPs due to crevice packing, are equivalent to expanded SG tubes. This potential effect includes SG tubes which have been plugged due to ODSCC flaws. The number of SG tubes which will be expanded at the TSP intersections is much smaller than the number of SG tubes previously plugged. We note that no adverse structural effects have been observed for plugged SG tubes during power ascension and the associated thermal cycling. On this basis, the staff concludes that no adverse effect will occur for the expanded SG tubes.

During power ascension to the SG operating temperature, differential thermal expansion between the active (i.e., unplugged) SG tubes and the plugged SG tubes, including the expanded SG tubes, will induce axial forces on the TSPs at the location of these plugged SG tubes. The magnitude of these induced thermal forces is much smaller than the forces applied by the tierods during the descent from power to cold shutdown conditions. Accordingly, the SG tube expansions do not introduce any significant new loading mechanisms for either the case of SG tube free to move relative to the TSPs or the SG tube/TSP lockup conditions. On this basis, the staff finds that plant operation with expanded SG tubes is enveloped by the existing operating conditions in the Byron, Unit 1, and Braidwood, Unit 1, SGs. Therefore, the staff finds that additional analyses are not required to provide assurance that these SGs with expanded SG tubes can be operated safely. In addition, acceptable operation under lockup conditions has been demonstrated by the field experience of operating SGs which have been shown by eddy current inspections to have SG tubes in the lockup condition.

4.4.7 Analysis Results for RELAP5 Loads

In the licensee's submittal dated October 13, 1995, the licensee describes the additional modifications which have been made to the finite element structural analysis model to evaluate the TSP displacements on the basis of the thermal-hydraulic loads calculated using RELAP5. The net effect of using this latest set of hydrodynamic loads was to require two additional tube expansions in the SG tube expansion matrix; the SG tube/TSP expansion zone interface model was also revised. In this revised structural analysis model, the SG tube and expansion zone stiffness are still in series with the TSP stiffness, but the analysis was revised to account for the SG tube stiffness at the upper TSPs not being affected by the SG tube expansions at the lower TSPs. The licensee's revision of this analytical representation more accurately models a SG tube expansion when more than one expansion zone exists along its length. The staff finds these revisions reasonable and, therefore, acceptable.

Another change made by the licensee which is not related to the SG tube bundle geometry, was revising the stiffness of the SG tubes in the expansion zone region. For these revised calculations, the licensee used an expansion zone stiffness value which is about 30% lower than the value used in the previous calculations discussed above. The revised value is more realistic since it is based on test data. The combined effect of these changes on the TSP displacements varies from TSP to TSP with the largest reduction in TSP displacements occurring in the upper TSPs.

The maximum displacements which were calculated using the RELAP5 differential pressure loads across the TSPs for the reference set of expansions (i.e., those documented in WCAP-14273 and its supplement) were provided by the licensee together with the maximum time-history TSP displacements using a non-linear TSP/spacer interaction. These results showed that all portions of the TSPs do not exceed the maximum allowable displacement limit of 0.10 inches, except for TSP L(8H). With the addition of two additional SG tube expansions (i.e., one for each half of the TSP) for TSP L(8H), the maximum time-history displacement was then shown to be less than the design criteria limiting value of 0.10 inches. The calculated results were provided for both a linear and a non-linear structural analysis to show the effect of the modeling assumptions.

The licensee used a smaller time step in its structural analysis in evaluating the RELAP5 pressure loads than that used when evaluating the TRANFLO pressure loads, due to the high frequency load oscillations which were calculated by RELAP5 during the initial stages of the MSLB transient (i.e., less than one second). The inclusion of the additional SG expansions for TSP L(8H), required the licensee to confirm that the selected degrees of freedom (DOF) still provided a close approximation of the TSP responses. Using the methodology and criteria of WCAP-14273 the licensee performed calculations for Plate L(8H) with the additional SG tube expansions cited above. A comparison of the natural frequencies for the full set of DOF and the reduced set of DOF showed that the reduced set of DOF provides a good approximation of the TSP response.

The licensee provided a summary of the final set of expansions, including the additional SG tube expansions for Plate L(8H). There was no change to the range of acceptable SG tube locations selected for expansion as described in WCAP-14273. The licensee also provided a plot showing the acceptable SG tube locations, including each group of alternate SG tube expansion locations. The staff finds that the structural analysis results based on the RELAP5 thermal-hydraulic differential pressure loads across the TSPs, are acceptable.

4.4.8 <u>Conclusions Regarding the Calculated TSP Displacements</u>

Based on its review of the structural analysis of the maximum TSP displacements discussed above, the staff concludes that the expansion of selected SG tubes at the TSP locations defined in the expansion matrix, provides an effective means of limiting SG TSP displacements during a postulated MSLB, to 0.100 inches or less. An evaluation of the resulting stresses demonstrated that the elastic analysis used by the licensee provides a good approximation of the dynamic response of the TSPs to the applied loading. On this basis, the staff finds that the licensee's analytical approach is reasonable and, therefore, acceptable.

Stress levels in the SG tubes, the TSPs and the supporting SG internal structural components were analyzed and found to be acceptable. The licensee has also shown that the SG tube expansions do not introduce any significant new loading mechanisms on the TSPs or on the TSP support structures for either the condition of a free SG tube expansion or with a postulated SG tube/TSP lockup condition. Accordingly, the staff finds that additional structural analyses are not required to provide assurance that the Byron, Unit 1, and Braidwood, Unit 1, SGs with expanded SG tubes, can be operated safely.

Based on the staff's review above, the staff finds that the licensee's structural analysis of the TSP displacements under loads imposed by a postulated MSLB, is acceptable.

4.5 <u>Steam Generator Tube Integrity</u>

4.5.1 <u>Introduction</u>

As discussed in Section 2.0 above, the licensee is proposing to use the free span model documented in GL 95-05 for predominantly axially oriented ODSCC indications at the cold-leg TSP elevations and at hot-leg TSP elevations adjacent to intersections which do not permit the passage of a 0.610-inch diameter bobbin coil probe. As discussed above, this condition is indicative of an unacceptable amount of denting. In addition, the licensee is proposing to implement the locked TSP model (i.e., implementing the SG tube expansions) for predominantly axially oriented ODSCC indications at the hot-leg TSP elevations as noted above. Each of these models is discussed below with emphasis on the locked TSP model since the free span model is described in detail in GL 95-05.

In the free span model, credit is taken for the TSPs in precluding the burst of indications at the TSP elevations under normal operating conditions. However, no credit is taken in this model for the TSPs reducing either the likelihood of SG tube burst or reducing SG tube leakage under transient and postulated accident conditions. In the locked TSP model, however, credit is taken for the constraint provided by the TSPs, thereby reducing the likelihood of SG tube axial tube burst and leakage under transient and postulated accident conditions. This is accomplished by evaluating the displacements of the TSPs under postulated accident conditions and limiting these displacements, as necessary, through the expansion of selected SG tubes at a number of TSP intersections. Since the TSP displacements are limited, the potential for predominantly axially oriented ODSCC indications at the TSP elevations to burst axially, is reduced to negligible levels since the relatively small clearance between the outer diameter of the SG tubes and the diameter of the TSP holes precludes an axial burst of a SG tube at these locations. As a result, the SG tube voltage-based repair limit need only be based on preventing SG tubes from failing under axial loads resulting from the pressure differential across the SG tubes.

In a fashion similar to the free span model, the potential for leakage from SG tube voltage indications accepted for continued service (i.e., bobbin voltages below 3.0 volts) is considered in the locked TSP model. However, unlike the free span model, the locked TSP leakage model also includes the potential leakage from ODSCC indications which attempt to burst axially, but can not due to the constraint provided by the TSPs (i.e., indications restricted from burst or IRBs). Both the free span model and the locked TSP model relate the bobbin coil voltage to the structural and leakage integrity of the predominantly axially oriented ODSCC indications at the TSP elevations; hence, both models are voltage-based models.

4.5.2 Steam Generator Tube Integrity Issues

The thin-walled tubing in the SG constitutes more than half of the reactor coolant pressure boundary (RCPB). Accordingly, maintenance of the structural and leakage integrity of this RCPB boundary in the SGs is a requirement under Title 10 of the Code of Federal Regulations, Part 50 (10 CFR 50), Appendix A. Specific requirements governing the maintenance of SG tube integrity are contained in the Byron, Unit 1, and Braidwood, Unit 1, TSs and Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code). These include requirements for periodic inservice inspection of the SG tubing, flaw acceptance criteria (i.e., repair limits for plugging or sleeving), and primary-to-secondary leakage limits for the SGs. These requirements, coupled with the broad scope of plant operational and maintenance programs, have formed the basis for assuring acceptable SG tube integrity.

Flaw acceptance criteria, termed plugging or repair limits, are contained in a plant's TSs. The purpose of the TS repair limits is to ensure that SG tubes 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 tube leakage within acceptable levels.

The traditional strategy for accomplishing the objectives of the GDC related to SG tube integrity has been to establish a minimum wall thickness requirement in accordance with the structural criteria in 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 then 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 flaw types currently occurring in the field and is the basis of the standard 40% depth-based repair limit incorporated into the Byron, Unit 1, and Braidwood, Unit 1, TSs. However, the 40% repair limit is conservative for highly localized flaws such as pits and short cracks. In particular, the 40% depth-based repair limit is conservative for ODSCC flaws which occur 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 providing 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 SG tube leakage have been established in a plant's TSs to provide reasonable assurance of a timely plant shutdown before adequate structural and leakage integrity of a SG tube which is leaking, is lost.

Voltage-based tube repair limits consist of voltage amplitude criteria rather than the traditional depth-based criteria. Thus, the voltage-based repair criteria represents a departure from the past practice of explicitly enforcing a minimum wall thickness requirement. As a result, many of the SG tubes which will be allowed to remain in service under the voltage-based repair criteria proposed in ComEd's submittal dated September 1, 1995, may have, or may develop, through-wall or near through-wall crack penetrations during the upcoming fuel cycles for Byron, Unit 1, and Braidwood, Unit 1, thereby creating the potential for leakage during normal operation and postulated MSLB accidents. The staff's evaluation of the proposed repair criteria from a structural and leakage integrity standpoint is provided in Sections 4.5.3 and 4.5.4 of this SE.

4.5.3 <u>Steam Generator Inspection Issues</u>

In support of the proposed voltage-based repair limits (i.e., both the free span model and the locked TSP model), the licensee proposed to utilize eddy current test guidelines which are intended to ensure that the inspection scope, the data acquisition, and the data analysis are performed in a manner consistent with the methodology utilized to develop the voltage repair limits. The proposed guidelines define, in part, the bobbin specifications, the calibration requirements, the specific data acquisition and analyses criteria, and the flaw recording guidelines to be used for the inspection of the SG tubes.

The licensee has indicated that it will follow the inspection guidance contained in GL 95-05. In addition, the licensee indicated that the following actions would be taken as a result of implementing the locked TSP model:

(a) SG tubes to be expanded and adjacent SG tubes will not contain corrosion-induced dents greater than 5.0 volts. This restriction will provide assurance of the integrity of the TSP ligaments at the SG tube expanded joints.

(b) All SG tubes selected for expansion at the TSPs will be required to have no detectable circumferential or axial degradation at the top of the tubesheet in the roll transition zone.

(c) The expanded SG tubes will be inspected following the expansion process to ensure that the desired expansion parameters have been achieved (i.e., bobbin profilometry). This inspection will ensure that the required bulge sizes have been achieved or that the need for corrective action is identified.

(d) Inspections shall be performed in the expanded SG tubes foll ing the expansion process with techniques capable of detecting both axially and circumferentially oriented indications in sleeved SG tubes. The purpose of these examinations is to ensure that no circumferential or axial cracks are present. If circumferential cracks are detected, the SG tube will be stabilized and plugged and an alternate SG tube selected for expansion.

(e) If corrosion-induced dents greater than 5 volts are found during future SG inspections at TSP intersections adjacent to expanded TSP intersections, the NRC will be informed. If a corrosion-induced dent greater than 5 volts were to develop in future operating cycles in a SG tube adjacent to an expanded SG tube, the structural integrity of the TSP ligaments adjacent to the expanded SG tube and its impact on limiting TSP displacements, will be evaluated. If additional SG tubes need to be expanded, they will be. The staff will also be informed if a 0.610-inch diameter probe fails to pass through a SG tube intersection adjacent to an expanded SG tube if this intersection has passed a 0.610-inch diameter probe in the past.

(f) If the periodic inspection of an expanded SG tube identifies a corrosion-induced dent greater than 5 volts, the need for expanding additional SG tubes will be evaluated. If this occurs, the NRC will be notified of the inspection findings and of the corrective action taken to resolve the findings.

(g) The staff will be notified prior to the licensee returning the SGs to service should any circumferential crack-like indications or primary water stress corrosion cracking (PWSCC) be detected at the TSP intersections, including any found in the expanded SG tubes.

(h) The staff will be notified if circumferential or axial cracks are found at the top of the tubesheet in the roll transition zone or at the intersections of the expanded SG tubes with the TSPs when the periodic inspections of these SG tubes are performed.

The licensee will follow the inspection guidance contained within GL 95-05 with the exception of: (1) the implementation of the probe wear guidance; and (2) the RPC inspection guidance at intersections where bobbin indications greater than 1.0 volt are detected. In this regard, the staff has allowed other plants to utilize, on a one operating cycle basis, the probe wear inspection methodology proposed by ComEd. Accordingly, the staff finds it acceptable for ComEd to implement this probe wear criteria for the Braidwood, Unit 1, and Byron, Unit 1, SG inspections during the present 1995 outages (i.e., the Braidwood, Unit 1, refueling outage and the Byron, Unit 1, mid-cycle outage). The staff, however, concludes that for future outages, the licensee should either: (a) provide an alternative probe wear methodology which provides detection and sizing capability equivalent to the probe wear guidance in GL 95-05; or (b) follow the GL 95-05 guidance with respect to probe wear.

The staff has also evaluated the licensee's exception to GL 95-05 regarding RPC inspections of bobbin indications. GL 95-05 guidance provides that RPC inspections should be performed at all TSP intersections where bobbin indications are greater than 1.0 volt for plants with 3/4-inch diameter SG tubes as is the case for the Braidwood, Unit 1, and Byron, Unit 1, SGs. The licensee has proposed to perform a 20% RPC inspection of all indications with bobbin voltages between 1.0 and 3.0 volts and a 100% RPC inspection of all indications above 3.0 volts. The 20% RPC sample of indications between 1.0 and 3.0 volts will be focused on new indications (i.e., those not previously examined by an RPC) and the larger bobbin voltage indications below 3.0 volts. The staff finds that the licensee's proposal is acceptable given that the locked TSP model will be implemented at these intersections rather than the free span model of GL 95-05. Further, the 20% sample will provide reasonable assurance that the degradation at the TSP intersections is predominantly axially oriented ODSCC.

The continued integrity of the expanded SG tubes is essential in limiting the TSP displacements, thereby ensuring the structural and leakage integrity of all the SG tubes. As a result, the licensee has proposed to reinspect a sample of these expanded SG tubes after three cycles of operation and to expand this sample based on the results of the SG inspection. The licensee's basis for three cycles of operation between SG inspections is discussed in its submittal dated September 1, 1995, and includes, in part, an evaluation of: (1) corrosion tests and operating experience for similar hydraulically expanded joints; (2) the observation that there is a low likelihood of a crack developing and affecting the ability of an expanded SG tube joint to function as designed for three cycles of operation; and (3) the use of redundant SG tube expansions to limit the TSP displacements which provides added margin in the event that circumferential severance of an expanded joint were to occur. Since the licensee is only proposing implementation of the locked TSP model repair criteria for one cycle of operation at Braidwood, Unit 1, and about one and a half cycles at Byron, Unit 1, the staff evaluated the integrity of these expanded SG tube joints for this limited time interval. The staff concludes that there is reasonable assurance of the structural integrity of the expanded SG tube joints for the proposed operating time interval for which these amendments are applicable. The staff notes, however, that additional information would be necessary to support the licensee's proposal to not inspect the expanded SG tubes during forthcoming SG inspections if the licensee requests to continue operation of the Byron 1 and Braidwood 1 SGs beyond the limited operational time approved by these amendments.

4.5.4 <u>Structural Integrity</u>

A SG tube can theoretically fail either axially or from axial tensile severing. The SG tube voltage repair limits for the free span model in GL 95-05 are based on limiting the potential for axial failures. Failures as a result of axial tensile loads are not expected as a result of implementing the repair criteria in GL 95-05 based on operating experience to date (i.e., burst testing). However, as voltage repair limits are raised for SG tubes with ODSCC flaws as in the present proposal by ComEd to implement the locked TSP model, the possibility that SG tube degradation may occur over a larger portion of the circumference of the SG tube at a given TSP elevation is increased; i.e., a circumferential band of closely spaced axial cracks with cellular corrosion and intergranular attack involvement, may develop. As a consequence, the potential for axial tensile severing of a SG tube is increased and, therefore, needs to be considered in the development of the SG tube voltage-based repair limits. In addition to establishing deterministic SG tube repair limits, probabilistic assessments of the potential for SG tube burst (i.e., both axial and axial tensile burst) need to be considered in the development of SG tube voltage-based repair criteria. Deterministic and probabilistic structural integrity assessments for both the free span and locked TSP models are discussed below.

4.5.4.1 Deterministic Structural Integrity Assessment

4.5.4.1.1 Deterministic Axial Structural Integrity Assessment

4.5.4.1.1.a Free Span Model

In the free span model, the SG tube voltage-based repair limits are based on a statistical correlation relating SG tube burst pressure to the bobbin coil voltage. This correlation was developed from both SG tube specimens removed from in-service SGs (using pre-pull bobbin voltages) and from SG tube specimens produced in the laboratory (i.e., model boiler specimens). The burst pressures for these SG tube specimens which contained ODSCC flaws, were determined without any constraining effect provided by a TSP. The bobbin voltage data used to construct the burst pressure/bobbin voltage statistical correlation, were normalized and are consistent with the calibration standard voltage set-ups and voltage measurement procedures to be used by the licensee during SG inspections at Byron, Unit 1, and Braidwood, Unit 1. When these SG tube specimens were burst tested, all of the failures were axially oriented. The SG tube repair limits are developed from this burst pressure correlation as discussed in GL 95-05. The lower voltage repair limit for 3/4-inch diameter SG tubes was established at 1.0 volt, and the upper voltage repair limit is about 2.7 volts, based on the historically observed growth rates and the limited cycle lengths at Byron, Unit 1, and Braidwood, Unit 1.

The free span voltage-based SG tube repair criteria have been set deterministically to ensure that indications accepted for continued service with these repair criteria will retain acceptable structural integrity during the full range of normal, transient, and postulated accident conditions for the limited operational cycles proposed by ComEd for Byron, Unit 1, and Braidwood, Unit 1. This repair criteria includes allowances for uncertainties in the eddy current inspections and in the SG tube ODSCC flaw growth projected to occur during the next operating cycle. Because the voltage-based repair criteria address SG tubes with ODSCC flaws 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 3 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 with respect to the SG tubes during a postulated blowdown such that the portion of the SG tubing affected by ODSCC may no longer be fully constrained by the TSPs. Accordingly, it is appropriate to consider the ODSCC affected regions of the tubes as free standing SG tubes for the purpose of assessing burst integrity under postulated MSLB conditions, unless it can be demonstrated that the movement of the TSPs under these conditions is minimal as was done by ComEd for the locked TSP model which is discussed below.

4.5.4.1.1.b Locked TSP Model

Since the form of degradation observed within the crevices of the TSPs is predominantly axially oriented ODSCC and occurs on the portion of the SG tube confined within the 0.75-inch thickness of the carbon steel TSPs, axial burst is precluded by the presence of the TSPs during normal operation. As a result, the guidance in RG 1.121 to maintain a margin of safety of at least 3 against SG tube rupture during normal operating conditions, is inherently satisfied at these locations.

With the locked TSP model, axial displacements of the TSPs can occur as a result of transients and postulated accident conditions (e.g., an MSLB). These displacements, however, are limited by expanding portions of several SG tubes into selected TSPs as discussed in Section 4.2 of this SE. If no TSP displacements were to occur, axial bursts of the SG tubes would be extremely unlikely since, as for the normal operating case, the amount an existing ODSCC crack can open is limited by the diametral gap between the outside diameter of the SG tubes and the diameter of the TSP holes. This diametral gap is sufficiently small to preclude SG tube burst although ODSCC cracks (i.e., indications) may attempt to burst, but are precluded from doing so as a result of the constraint provided by the TSPs. Indications which attempt to burst, but are precluded from doing so are referred to as IRBs. The leakage which can result from IRBs is addressed in Section 4.5.4 of this SE.

By limiting the displacement of the TSPs, the extent of ODSCC degradation exposed outside the TSPs during transients and postulated accidents is limited to the amount of the TSP displacements since ODSCC degradation is confined to that portion of the SG tubes within the TSP thickness. Given the SG tube expansion matrix proposed by the licensee, the TSP displacements have been limited to a maximum value of 0.10 inches or less. As a result, a maximum exposure not exceeding 0.10 inches of a postulated 0.75-inch long ODSCC indication would be exposed outside the TSPs. (The staff has conservatively assumed that the longest possible ODSCC indication is 0.75-inch based on the thickness of the TSPs). This conservative bound for the length of an ODSCC flaw does not exceed the thickness of the TSPs since the repair criteria proposed by ComEd only applies to ODSCC degradation in that portion of the SG tubes which is confined within the thickness of the TSPs. If the degradation extends outside the thickness of the TSPs, the voltage-based repair limit of 3.0 volts would not be applied. Additionally, if ODSCC degradation is found outside the TSPs during the non-destructive eddy current examinations, the licensee will report this occurrence to the NRC prior to returning the SGs of Byron, Unit 1, and Braidwood, Unit 1, to service.

To assess the significance of axial indications, the licensee has provided a statistical correlation between burst pressure and axial crack length. Without the constraint provided by the TSP, a 0.75-inch free span ODSCC indication in a SG tube with lower bound material properties (i.e., 95%/95%) would have a SG tube burst pressure close to the differential pressures anticipated inside the SG tubes during a postulated MSLB. However, if it is postulated that the TSPs have relatively small displacements and cover 0.65 inches of a 0.75-inch ODSCC indication, the SG tube burst pressure should be much higher than the differential pressure inside the SG tubes under MSLB conditions. The licensee provided test results to support such a conclusion.

These tests provided a direct comparison between the free span SG tube burst strength and the burst strength of a SG tube constrained by a TSP.

For the TSP constrained burst tests, electric discharge machined (EDM) notches 0.70 inches in length were confined within a simulated TSP designed to provide the same radial stiffness as a TSP within the Model D4 SGs at Byron, Unit 1, and Braidwood, Unit 1. In addition, the diametral gap between the SG tube test specimen and the simulated TSP ranged from 11 to 23 mils. A diametral gap of 23 mils represents an upper 95% confidence bound on the expected tube-to-TSP gap. The results of the testing confirmed that ODSCC type cracks which have portions of this crack confined within the thickness of the TSPs and exposed lengths typical of the maximum expected TSP displacements (i.e., 0.10 inches) have burst pressures much higher than the burst pressure corresponding to the total free span length of the ODSCC crack. In fact, the SG tube specimen burst pressure was primarily a function of the exposed ODSCC crack length rather than the total crack length. As a result, the burst pressure of a 0.75-inch long crack of which only 0.10 inches is exposed outside a TSP, will have a burst pressure corresponding to a 0.10-inch long ODSCC crack. This burst pressure will be greater than 7000 pounds per square inch (psi) which is well above the differential pressure loading criteria in RG 1.121. However, as the tube-to-TSP clearances increase (i.e., the diameter of the TSP hole is increased), some reduction in the SG tube burst pressure of an exposed ODSCC crack may occur compared to a comparable free span crack. This was observed in the tests conducted by ComEd. However, for a 23 mil gap representing the upper 95% confidence bound and the maximum expected TSP displacements (i.e., 0.10-inches), the reduction in the SG tube specimen burst pressure was less than 1000 psi. Even with this reduction in the SG tube burst pressure of 1000 psi, the resultant 6000 psi burst pressure capability of the SG tubes is still well above the pressure loading criteria contained in RG 1.121.

4.5.4.1.1.c <u>Conclusion Regarding the Deterministic Axial Structural Integrity of SG Tubes</u>

For the free span model which is to be applied to cold-leg TSP intersections and certain intersections adjacent to dented hot-leg TSP intersections, the staff concludes that the methodology discussed in GL 95-05 for the development of the deterministic SG tube voltage repair limits provides adequate margin against axial burst during normal operating, transient, and postulated accident conditions.

For the locked TSP model which is to be applied to the hot-leg TSP intersections, the test program conducted by the licensee indicated that the SG tube burst pressure for an axial crack extending outside the TSPs is a function of the exposed ODSCC crack length outside the TSPs rather than the total ODSCC crack length, and the SG tube burst pressure for cracks that extend outside the TSP is only slightly reduced (i.e., less than 1000 psi) at larger than nominal tube-to-TSP diametral gaps when compared to a postulated free span ODSCC crack of the same length for the maximum 0.10-inch displacements postulated by the licensee. The staff notes, however, that this testing does not consider the effect of many closely spaced axial cracks which may result in further reductions in the SG tube burst pressure. Despite this, the staff concludes, based on operating experience and the testing to date, that for the SG tube degradation mechanism (i.e., ODSCC) for which this voltage-based repair criteria will be applied, the potential to burst a single axial ODSCC indication which is exposed by 0.10-inch is negligible. The operating experience and testing to date indicates that: (1) the SG tube burst capability is dominated by the length and depth profile of the most limiting ODSCC macrocrack; and (2) the ODSCC degradation is generally centered in the TSPs rather than at the edge of the TSPs. As a result, an acceptable margin against axial burst of a single predominantly axially oriented ODSCC indication during normal operating, transient, and postulated accident conditions, is ensured both by determining from eddy current inspections that all ODSCC indications remain in those portions of the SG tube which are confined within the TSP thickness and by limiting the displacement of the TSPs to a maximum value of 0.10 inches.

For indications at the flow distribution baffle TSP, the licensee will implement the depth-based SG tube repair criteria presently in the Byron, Unit 1, and Braidwood, Unit 1, TSs.

4.5.4.1.2 Deterministic Axial Tensile Structural Integrity Assessment

4.5.4.1.2.a Free Span Model

As discussed in Section 4.5.3.1.a of this SE, the free span model SG tube voltage repair limits are based on a statistical correlation relating SG tube burst pressures to the bobbin coil voltage. During the testing performed by the utility industry to support the development of the SG tube voltage repair limits in GL 95-05, all of the observed SG tube bursts were axially oriented even for ODSCC indications that had bobbin voltages up to 20 volts. Since ODSCC degradation is predominantly axially oriented, circumferential failure of the ODSCC indications to which the free span model is applied, is not expected for the voltage repair limits in the current Byron, Unit 1, and Braidwood, Unit 1, TSs and the bobbin voltages currently being observed in the SG eddy current inspections of these two units. As a result, the deterministic voltage repair limit for addressing axial failures conservatively bounds any deterministic voltage-based repair limit which would be necessary for addressing the potential for circumferential failures.

4.5.4.1.2.b Locked TSP Model

As the circumferential involvement of the predominantly axially oriented ODSCC degradation on those portions of the SG tubes within the thickness of the TSPs progresses, the potential for axial tensile severance of a SG tube as a result of the axial forces acting on the SG tube increases. The circumferential involvement arises due to the development of closely spaced ODSCC axial cracks, cellular corrosion, and/or intergranular attack (IGA) corrosion. The axial loads result from the pressure differential across the SG tubes. To ensure that predominantly axially oriented ODSCC indications which are accepted for continued service at the TSP elevations, will have adequate margin during normal operating, transient, and postulated accident conditions, statistical correlations relating the tensile load carrying capability (i.e., relating the tensile force and the residual cross-sectional (RCS) area) to the associated bobbin voltage have been developed as discussed below.

The licensee has provided two different types of statistical correlations to relate the axial load carrying capability of a predominantly axially oriented ODSCC indication to the associated bobbin voltage. One type of correlation relates the RCS area to the bobbin voltage. The other correlation, which contains a subset of the data used in the RCS area correlation, relates the axial tensile force for axial separation to the associated bobbin voltage. The bobbin voltage data used to construct these statistical correlations 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 at Byron, Unit 1, and Braidwood, Unit 1. We note that the bobbin voltages for several IGA specimens provided by the licensee were not obtained in a manner consistent with the voltage normalization procedure in GL 95-05 and, therefore, are not included in these correlations. The structural limit is determined from these correlations by evaluating them at 3 times the normal operating pressure loading condition, the most limiting of the structural loading guidelines in RG 1.121.

The data used in the correlation relating RCS area to bobbin voltage are derived from a variety of sources. This data include both 3/4-inch and 7/8-inch diameter SG tubes combined into one database, unlike the free span model for axial burst which separates the 3/4-inch and 7/8-inch diameter SG tubing data into two databases. The data also include SG tube specimens which had cellular and/or IGA corrosion. The licensee has concluded that the data from SG tube specimens with cellular corrosion should primarily be used in determining the structural limit since: (1) the SG tube specimens had the expected ODSCC crack morphology; (2) only one SG tube has been found with significant IGA involvement and this SG tube was plugged a few years prior to pulling it; and (3) circumferential cracks are not expected at non-dented intersections (i.e., dents less than 5 volts); and (4) the voltage-based repair criteria are not applied to circumferential cracks.

Since the specimens used in the database were not necessarily specifically tested to support the determination of a structural limit for axial tensile failure, the RCS area for these specimens was calculated by a variety of methods. That is, the method used to calculate the RCS area for a specific SG tube specimen is dependent on the destructive analyses performed on the SG tube specimens at the time they were examined. Methods used to calculate the RCS area include: (1) a calculation using tensile strength data; (2) a calculation of the non-degraded RCS area by evaluating the circumferential depth profile of the degradation; (3) a calculation of the non-degraded RCS area by evaluating the average depth of the indications and the circumferential extent of the degradation; (4) a calculation of the non-degraded RCS area by evaluating the average depth of the indications and assuming the circumferential extent is 360°; and (5) a calculation using the ratio of the degraded rupture force to the free span rupture force. In addition, for one set of specimens, the RCS area was determined based on a non-destructive evaluation (NDE) of the depth of the SG tube degradation.

A linear statistical correlation relating the RCS area to the bobbin voltage has been developed from the data discussed above. Specifically, a linear first order equation between the non-degraded RCS area and the bobbin voltage was determined using a standard least-squares, linear regression analysis. From this regression relationship, a lower 95 percent prediction bound was determined for the non-degraded RCS area as a function of the bobbin voltage amplitude. The lower 95 percent prediction interval was further reduced to account for temperature effects on the SG tube material properties; i.e., the lower bound was reduced by the ratio of the flow stress at high temperature (i.e., 650°F) to the flow stress at room temperature from the more conservative of the ratios from 3/4-inch or 7/8-inch diameter SG tubing material properties. Using this reduced lower prediction interval curve, the structural limit for axial tensile failure is determined for a pressure loading corresponding to 3 times the normal operating differential pressure consistent with the guidance on structural limits in RG 1.121. This evaluation was done using lower tolerance limit material properties. With this approach, the licensee determined that a voltage-based repair structural limit of about 35 volts was appropriate.

Due to the potential for introducing uncertainty by using a variety of methods to calculate the RCS area as discussed above, the staff requested the licensee to provide a second assessment relating the axial load carrying capability of a predominantly axially oriented ODSCC indication in a SG tube to the bobbin voltage. This approach involved relating the axial force required to fail a predominantly axially oriented ODSCC indication to the bobbin voltage. Accordingly, a statistical correlation between the axial force and the logarithm of the bobbin voltage was developed. Applying similar statistical analyses as discussed above (i.e., establishing a lower 95% prediction interval, making adjustments for lower bound (95%/95%) material properties, and evaluating the axial load imposed by an internal differential pressure 3 times the normal operating differential pressure), the resulting voltage-based structural repair limit to provide assurance against axial tensile failure of a SG tube, was calculated to be in excess of 100 volts. This determination is, therefore, less conservative than the previous evaluation.

To provide a more conservative determination of the SG tube voltage-based structural repair limit, the licensee adjusted downward the lower value of the two structural limits cited above (i.e., 35 volts) to account for the limited size of the database. On this basis, the licensee established a lower bound voltage-based structural repair limit of 20 volts. This structural limit was then further adjusted downward to account for potential flaw growth during an operating interval of one cycle and to account for uncertainties in the NDE eddy current inspections. Adjustments of the voltage-based structural repair limit to account for flaw growth and NDE uncertainty are discussed in RG 1.121. The licensee concluded that a repair limit exceeding 10 volts was justified. However, for added conservatism, the licensee further reduced the voltage-based structural repair limit to 3.0 volts. As a result, the licensee has proposed to repair all bobbin indications above 3.0 volts, regardless of RPC results.

4.5.4.1.2.c Conclusions Regarding the Deterministic Axial Tensile Structural Integrity of SG Tubes

For the free span model, which is to be applied primarily to cold-leg TSP intersections, the staff concludes that the methodology discussed in GL 95-05 for the development of the voltage-based repair limits demonstrates an acceptable margin against tensile severing during normal operating, transient, and postulated accident conditions. This conclusion is supported by the data discussed in Section 4.5.3.2.b of this SE.

For the locked TSP model, which is to be applied to selected hot-leg TSP intersections, the statistical correlations of non-degraded RCS area to the associated bobbin voltage and the correlation of axial rupture force to the logarithm of the associated bobbin voltage, indicate acceptable structural limits above 30 volts. The staff agrees with the licensee's conclusion that additional data are needed to better define this estimate of the voltage-based structural limit. The staff notes that uncertainty and potential non-conservatisms are introduced into these statistical correlations through the following sources: (1) using several different methods to calculate the RCS area; (2) adjusting the data based on the flow stress and/or ultimate strength of the SG tube specimens for data normalization; (3) assuming lateral restraint of the SG tubes; (4) using specimens for which no destructive analyses data were available (i.e., NDE depth estimates were used, including a 5% adder); (5) using a mean value of the tensile strength for the pulled SG tube database to normalize the laboratory IGA SG tube specimens; (6) using the mean value of the ultimate strength for the pulled SG tube database to normalize the TSP constrained SG tube burst test data; (7) using nominal SG tube dimensions; and (8) excluding IGA specimens obtained in a manner consistent with the criteria in GL 95-05 since some SG tubes have IGA involvement at the TSP elevations (e.g., previously plugged tubes). The staff notes that the statistical correlation between the axial rupture force and the logarithm of the bobbin voltage is the preferred approach for developing this type of correlation. However, the staff also notes that there is a minimal amount of data supporting such a correlation.

Nonetheless, the staff has evaluated the acceptability of the proposed 3.0 volt SG tube voltage-based repair criteria proposed by ComEd to be implemented as part of the locked TSP approach. Since the locked TSP approach is a voltage-based approach with data acquisition and analysis criteria similar to that contained in GL 95-05, the staff considers the NDE uncertainty models discussed in GL 95-05 to be applicable to the locked TSP model. In addition, the staff considers the GL 95-05 methodology for determining growth rates to be applicable to the locked TSP model. To evaluate the acceptability of the 3.0 volt repair limit, the staff considered both the maximum voltage growth observed in the Byron, Unit 1, and Braidwood, Unit 1, SGs and the 95% cumulative probability value for the NDE uncertainty (i.e., 20% of the beginning-of-cycle (BOC) voltages). The maximum voltage growth at Braidwood, Unit 1, and Byron, Unit 1, was 8.51 volts per effective full power years (EFPY). Taking into consideration the limited operating intervals proposed by ComEd for both Byron, Unit 1, and Braidwood, Unit 1, and the largest ODSCC indication which can be left in service (i.e., 3.0 volts), the maximum end-of-cycle (EOC) voltage is expected to be about 14 volts. This value is considerably less than the calculated voltage-based structural limit discussed above. Taking into consideration this maximum expected EOC bobbin voltage, the potential non-conservatisms discussed above, and the observation that no SG tube specimens used in support of the free span model, failed as a result of axial tensile loads even with bobbin voltages in excess of 20 volts for 3/4-inch diameter SG tubing, the staff concludes that a 3.0 volt repair limit is acceptable through Cycle 6 at Braidwood, Unit 1, and through Cycle 8 at Byron, Unit 1.

For flow distribution baffle indications, the licensee will implement the depth-based SG tube repair criteria presently in the Byron, Unit 1, and Braidwood, Unit 1, TSs.

4.5.4.2 Probabilistic Structural Integrity Assessment

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

(a) The deterministic analysis does not consider any of the following items: (1) the tail of the statistical correlation involving the SG tube burst pressure versus bobbin voltage for the free span model; (2) the RCS area versus the associated bobbin voltage; and (3) the axial tensile force versus the logarithm of the bobbin voltage for the locked TSP model beyond the lower 95% prediction interval used to determine the voltage-based structural limit. Given the large numbers of indications which could potentially be accepted for continued service with the voltage repair criteria proposed by ComEd, the probabilistic analysis ensures that the use of the 95% prediction interval value in lieu of either 99% or 99.9% lower bound values, does not lead to a significant likelihood of a SG tube rupture, given an MSLB.

(b) The deterministic assessment ignores the burst and leakage potential of bobbin voltage indications between the lower and the upper voltage repair limits for bobbin indications which were not confirmed by the RPC probe. The probabilistic assessment, however, considers the burst potential of these bobbin indications with no credit taken for the lack of confirmation by the RPC probe of the presence of these ODSCC indications. This item is applicable only to the free span model since only one voltage limit is utilized in the locked TSP model.

(c) The deterministic analysis does not account for bobbin indications missed by the data analysts. Accordingly, the probabilistic assessment is necessary to address the burst potential of ODSCC indications missed by the data analysts.

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

(e) The deterministic analysis does not consider the tails of the material properties distribution and the variability of the distributions of the eddy current inspections. The probabilistic analysis does, however, include the entire distribution of material properties and eddy current voltage variability.

To perform the probabilistic analysis for determining the conditional probability of burst given an MSLB, the EOC distribution of indications must first be determined. The determination of this EOC voltage distribution is discussed in GL 95-05. The methodology of the free span model and the locked TSP model are similar. However, the licensee will determine separate EOC distributions for the intersections to which the locked TSP model and free span model are applied. These separate EOC distributions will be determined from the growth rate distributions determined from the appropriate indications. Specifically, the SG tube intersections to which the locked TSP model will be applied will have a separate growth rate distribution from the SG tube intersections to which the free span model is applied. However, if the free span model is applied to a limited number of indications (i.e., about 200 as defined in GL 95-05), a bounding growth rate distribution will be used in the determination of the EOC voltage distribution.

Since the two distinct models cited above are being employed to address the structural integrity of ODSCC indications at the TSP elevations in the SGs, two distinct models for calculating the probability of burst have been developed; i.e., the free span model and the locked TSP model. Each model must address the probability that an indication can either fail in the axial direction under MSLB conditions or can fail as a result of axial tensile loadings under MSLB conditions.

4.5.4.2.1 Probabilistic Axial Structural Integrity Assessment

4.5.4.2.1.a Free Span Model

For the free span model, it is assumed that the TSPs do not provide any constraint to the ODSCC degradation. The methodology for calculating the conditional probability of one or more SG tubes failing axially during a postulated MSLB is discussed in GL 95-05 and in the staff's memorandum dated May 30, 1995, from Mr. Frank J. Miraglia to Mr. Edward L. Jordan, titled "Request for CRGR Review of Generic Letter 95-XX, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter

Stress Corrosion Cracking." The licensee has proposed to perform this calculation in accordance with GL 95-05 which is the approved version of GL 95-XX cited above.

4.5.4.2.1.b Locked TSP Model

As with the free span model, a model for assessing the conditional probability of SG tube axial burst given an MSLB, for ODSCC indications at the TSPs, has been developed. However, unlike the free span model, the constraining effect of the TSPs is considered in the locked TSP model. This consideration of the constraining effect of the TSPs is acceptable based on the licensee's demonstration that the displacement of the TSPs does not exceed 0.10 inches as discussed above.

To demonstrate the constraining effect of the TSPs, the licensee has provided two correlations relating the axial length of a cracked SG tube specimen to the burst pressure of the specimen. The first correlation is a free span correlation which simply relates the burst pressure of a SG tube specimen to the total through-wall crack length. This correlation is discussed in an Electric Power Research Institute (EPRI) report, titled "Burst Pressure Correlation for Steam Generator Tubes with Throughwall Axial Cracks," dated February 1995. The second correlation is one taking credit for the constraint provided by a TSP and which relates the burst strength of a SG tube specimen to the through-wall crack length outside the TSP (i.e., the exposed through-wall crack length).

The correlation provided in the EPRI report cited above indicates that on average, a 0.75-inch free span indication in a 3/4-inch diameter SG tube would be expected to have a burst pressure of about 2800 psi. This ODSCC length is the maximum indication expected since the ODSCC degradation is confined within the TSP crevice region where a chemical environment conducive to the development of ODSCC flaws exists. This SG tube burst pressure is very near the maximum differential pressure inside a SG tube which is expected during an MSLB. However, in the locked TSP model, the maximum displacement of the TSPs will be 0.10 inches or less. As a result, only 0.10 inches of the total maximum possible length of an ODSCC flaw would be exposed during a postulated MSLB. Since the TSPs will restrain the crack both in the radial and circumferential directions as a result of the small diametral clearance between the outside diameter of the tube and the diameter of the TSP holes, the burst pressure will be significantly higher than 2800 psi.

To determine the effect of the constraint provided by the TSPs, the licensee performed a SG tube specimen burst test program which demonstrated that the burst pressure for an ODSCC type flaw indication is primarily a function of the through-wall crack length exposed outside the TSPs. That is, if 0.10 inches of a 0.75-inch through-wall crack is exposed outside the TSPs, the SG tube burst pressure expected for this situation would be very near the burst pressure for a 0.100 inch free span through-wall crack. The test program supporting this conclusion included: (1) simulating the constraint provided by a TSP by using a round collar which was sized to provide a radial stiffness equal to the radial stiffness of the TSPs; and (2) varying the diametral clearance between the SG tube specimens and the TSP hole within the range of expected diametral gaps. Based on this testing, the licensee concluded that for long, free span cracks with a portion of the crack exposed outside the TSPs with a small TSP gap of about 13 mils, the SG tube burst pressure was very near that of a free span ODSCC crack with a total length equal to the exposed length of the constrained ODSCC crack. In summary, the testing showed that the portion of the crack confined within the TSPs has little or no effect on the burst pressure of the SG tubes. Based on this test program, the licensee also concluded that as the TSP diametral gap increased, the constraining effect provided by the TSP would not be as significant. However, for a 95% upper confidence bound on the diametral gap, the licensee concluded that for the amount of crack exposure expected in the locked TSP model (i.e., a maximum value of 0.10 inches), a small reduction in the predicted SG tube burst pressure would occur. Specifically, if 0.10 inches of a 0.75-inch through-wall crack is exposed outside the TSPs with a diametral gap at the 95% upper confidence bound, the SG tube burst pressure is slightly less than the free span SG tube burst pressure of a 0.10 inch through-wall crack.

To assess the conditional probability of a SG tube axial burst given an MSLB, the licensee performed a calculation assuming all hot-leg TSP locations had a 0.75-inch long through-wall crack of which a portion of the crack was displaced outside the TSPs by an amount equal to the maximum TSP displacement of 0.10 inches. In addition, the licensee also assumed that the diametral gap between the SG tubes and the TSP holes for all intersections was at the upper 95% confidence bound. This calculation utilized the burst pressure versus axial crack length statistical correlation provided in the EPRI report cited above with an appropriate reduction in the burst pressure for the tube-to-TSP diametral gap as also discussed above. The result was that the probability of axial burst under MSLB conditions was negligibly low. To assess the effect of increased TSP displacements on the axial burst probability under MSLB conditions, the licensee also performed calculations at other TSP displacements. For example, even if the TSP displacement were to be as large as 0.31 inches, the axial burst probability under MSLB conditions at the EOC was calculated to be on the order of 10^{-5}, which is well below the threshold screening criteria of $1x10^{-2}$ in GL 95-05.

4.5.4.2.2 Probabilistic Axial Tensile Structural Integrity Assessment

4.5.4.2.2.a Free Span Model

As discussed in Section 4.5.3.1.a of this SE, the free span model SG tube repair limits are based on a statistical correlation relating SG tube burst pressure to bobbin coil voltage. During the testing performed to support the development of the SG tube repair limits, all of the observed bursts were axially oriented even for ODSCC indications with bobbin voltages up to 20 volts. Since the degradation is predominantly axially oriented, failure of the ODSCC indications as a result of axial tensile loads is not expected for the voltage repair limits being implemented in the subject license amendments and the bobbin voltages currently being observed in the field. As a result, the probability of axial tensile burst given an MSLB, is negligible.

4.5.4.2.2.b Locked TSP Model

As discussed in Section 4.5.3.2 of this SE, the probability of an axial SG tube tensile burst given an MSLB, must also be considered. The licensee stated that a calculation of the probability of axial tensile burst is not necessary for the voltage-based repair limits being implemented (i.e., 3.0 volts). ComEd's basis for its position involves examining the conditional probability of axial tensile burst of a single ODSCC indication under MSLB conditions which was evaluated deterministically. The licensee stated that this overestimates the burst probability when compared to the probabilistic Monte Carlo simulations performed in accordance with the guidance in GL 95-05. For this analysis, the licensee reported the conditional probability of axial SG tube tensile burst, given an MSLB, for a single indication using two different correlations. These were: (1) the RCS area versus bobbin voltage correlation; and (2) the tensile force versus the logarithm of the bobbin voltage correlation. The results indicated that the conditional probability of axial tensile burst was on the order of $3x10^{-5}$ from the first correlation cited and $3x10^{-6}$ for the second correlation, assuming a single 10 volt indication under MSLB conditions. As a result of these low probabilities and the low likelihood of developing a large number of ODSCC indications in the 10 to 15 volt range when implementing the proposed 3 volt repair limit at Byron, Unit 1, and Braidwood, Unit 1, the licensee concluded that the axial tensile burst probability given an MSLB, need not be calculated.

4.5.4.2.3 Conclusions Regarding the Probabalistic Axial Tensile Structural Integrity of SG Tubes

For ODSCC indications to which the free span model will be applied (i.e., primarily cold-leg intersections and intersections adjacent to dented intersections), the methodology described in GL 95-05 will be implemented to calculate the conditional probability of axial burst, given an MSLB. The staff finds this methodology acceptable. Given an MSLB, the staff finds that the conditional probability of axial tensile burst when applying the free span model, is negligible based on the voltage repair limits being implemented at Byron, Unit 1, and Braidwood, Unit 1, in accordance with GL 95-05 and the bobbin voltages currently being observed in the field.

As discussed in Section 4.5.3.2.1.b of this SE, the conditional probability of a SG tube axial burst when applying the locked TSP model, given an MSLB, was determined to be negligible. This probability was calculated assuming all intersections have through-wall cracks whose length is equal to the thickness of the TSPs (i.e., 0.75 inches) of which a maximum of 0.10 inches may be exposed during an MSLB (i.e., the maximum TSP displacement). The licensee also evaluated the effects on SG tube axial bursts probabilities if the TSP displacements were larger than 0.10 inches. For one of the cases analyzed, a conditional probability of axial burst, given an MSLB, was determined to be on the order of 10^{-5}, assuming a TSP displacement of 0.31 inches. The staff reviewed the information provided by the licensee and concludes that the conditional probability of axial burst, given an MSLB, when applying the locked TSP model and with TSPs displacements limited to a maximum value of 0.10 inches, is negligible. Although the staff's review of the information submitted by ComEd identified areas where it appeared that either non-conservative adjustments were potentially being made to the data (e.g., adjustment of the burst pressure to account for the use of foil-reinforced bladders), or that non-conservative assumptions were being made (refer to Section 4.5.3.1.1.c of this SE), the staff concludes that these factors would not affect its overall conclusion regarding the acceptability of the proposed voltage repair limits in light of the limited operating intervals being considered for Byron, Unit 1, and Braidwood, Unit 1. As a result, the staff concludes that the licensee's analysis provides reasonable assurance that the probability of axial SG tube burst given an MSLB, for ODSCC indications exposed by no greater than 0.10 inches outside the TSPs, would be extremely low. This conclusion is based, in part, on compensating conservative assumptions made in the licensee's submittal such as assuming: (1) all hot-leg TSP intersections have through-wall cracks extending the length of the TSPs; and (2) the amount of ODSCC crack exposure at every TSP location is equal to the maximum limiting TSP displacement of 0.10 inches.

For the locked TSP model, the potential for axial SG tube tensile burst increases since it has been proposed to increase the lower voltage repair limit from 1.0 to 3.0 volts. The licensee has stated that the conditional probability of an axial SG tube tensile burst, given an MSLB, is negligible when implementing the 3.0 volt repair criteria. The staff agrees that for remaining portion of the present fuel cycle of Byron, Unit 1, from the present mid-cycle outage to March 1996 and thence through cycle 8 and for a full operating fuel cycle for Braidwood, Unit 1, that the conditional probability of axial tensile burst, given an MSLB, is negligible. However, the staff notes that the database and statistical correlations supporting this conclusion need to be continually assessed, including the EOC voltage distributions which will be found at Byron, Unit 1, and Braidwood, Unit 1, to ensure that the probability of axial tensile burst, given an MSLB, will remain negligible. In addition, the staff concludes that: (1) all probabilistic calculations of SG tube tensile axial burst should be performed in accordance with the methodology described in GL 95-05 (i.e., using a probabilistic Monte Carlo analysis); and (2) any future submittals on this issue should address a means of combining the axial and the axial tensile burst probabilities. However, as noted above, based on the current estimated projections of the voltage distributions at EOC for Byron, Unit 1, and Braidwood, Unit 1, the staff concludes that not calculating the conditional probability of axial tensile burst given an MSLB, is acceptable for operating one fuel cycle at Braidwood, Unit 1, and one and a half fuel cycles at Byron, Unit 1.

The results of the probabilistic analyses discussed above will be compared to the threshold screening value of $1x10^{-2}$ in GL 95-05. This threshold value provides assurance that the conditional probability of burst, given an MSLB, is acceptable considering the assumptions in the calculations and the results of 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". Exceeding the threshold value cited above indicates that ODSCC flaws confined within the thickness of the TSPs could contribute a significantly larger fraction to the overall conditional probability of SG tube rupture from all forms of degradation than was assumed and found to be acceptable in NUREG-0844. In addition, this threshold screening value in GL 95-05 provides an indication that one or more SG tubes may not maintain the RG 1.121 safety margins for an entire operating cycle. If this threshold value is exceeded, the NRC staff will be notified by the licensee and an assessment of the safety significance of this occurrence will be provided to the NRC staff by the licensee prior to returning the affected SGs to service.

4.5.4.3 Confirmation of Degradation Mechanism

GL 95-05 provides a discussion on the purpose, frequency, and scope of pulling SG tubes for destructive examination. The licensee has committed to follow the SG tube pull guidance in GL 95-05. However, since GL 95-05 only addresses the free span model where SG tube axial tensile failure is not expected, GL 95-05 does address performing testing on pulled SG tubes to provide data for the axial tensile failure correlation database (i.e., the correlation between the axial tensile force for axial tensile burst severance versus the logarithm of the bobbin voltage). As a result, the licensee has committed to supplement the axial tensile failure database by performing the tensile force tests on specimens removed in accordance with the GL 95-05 guidance for the free span axial burst tests.

Destructive metallurgical examinations of TSP intersections removed from Braidwood, Unit 1, and Byron, Unit 1, have confirmed that the dominant degradation mechanism for the indications at the TSP elevations is primarily axially oriented ODSCC and that the voltage-based SG tube repair criteria for ODSCC indications at the TSPs is applicable. Further evidence that the degradation morphology of the SG tubes at Byron, Unit 1, and Braidwood, Unit 1, is consistent with that assumed in GL 95-05 will be obtained from the RPC examinations to be performed by the licensee during planned outages as discussed in Section 4.5.2 of this SE.

4.5.5 Leakage Integrity of Steam Generator Tubes

An important implication of the free span and the locked TSP voltage-based SG tube repair criteria is that these criteria may permit tubes to have, or to develop, through-wall or near through-wall cracks during the forthcoming operational cycles at Byron, Unit 1, and Braidwood, Unit 1, thereby creating the potential for primary-to-secondary SG tube leakage during normal operating, transient, or postulated accident conditions. Accordingly, the leakage integrity of these SG tubes, in addition to their structural integrity, must be assessed.

The staff finds that acceptable leakage integrity of the SG tubes during normal operating conditions is reasonably assured by the TS limits on allowable primary-to-secondary leakage presently in the Byron, Unit 1, and Braidwood, Unit 1, TSs. Acceptable leakage integrity during transients and postulated accidents is demonstrated by showing that for the most limiting accident, assumed to occur at EOC, the resulting leakage will not exceed a rate that will result in offsite dose limits exceeding a small fraction of the guideline values in 10 CFR Part 100. The radiological consequences of this is discussed in Section 4.6 of this SE.

4.5.5.1 Normal Operational Leakage

The licensee has implemented a primary-to-secondary leakage limit in its TSs of 150 gallons per day through any one SG. The staff finds that this limit on operational leakage is acceptable because it provides assurance that a SG tube which has developed a measurable leak will be either repaired or removed from service prior to development of a flaw which would result in an offsite release of radiation which would exceed a small fraction of the guideline radiation limits in 10 CFR Part 100 in the event of an MSLB as discussed in GL 95-05.

4.5.5.2 Accident Leakage

In the free span model, most of the ODSCC indications accepted for continued service have free span burst pressures above the differential pressure inside the SG tube resulting from a postulated MSLB. However, there is a small, but finite probability that ODSCC indications may burst at a differential pressure less than the MSLB differential pressure inside the SG tubes. Accordingly, GL 95-05 contains guidance to the effect that if this conditional probability exceeds $1x10^{-2}$, it must be reported to the NRC. For the locked TSP model, the conditional probability of axial burst, given an MSLB, is negligible as discussed in Section 4.5.3.2.1.b of this SE. However, in the locked TSP model in which ComEd proposed a larger voltage limit, the probability that an ODSCC indication may attempt to burst, but be precluded from doing so as a result of the flanks of the SG tube crack opening up and contacting the edges of the TSP hole (i.e., an IRB), is increased. Leakage from an IRB may potentially exceed that calculated using the free span leak rate correlation discussed in GL 95-05 since this correlation does not include SG tube specimens which start to burst at or below MSLB conditions. The licensee has performed laboratory testing on IRBs to determine the leak rate attributable to an IRB as discussed below.

The licensee has proposed a model for calculating the SG tube leakage from the faulted SG during a postulated MSLB which consists of the following two major components: (1) a model for predicting the leakage from ODSCC indications, assuming that the indications are in the free span (i.e., the free span leakage model); and (2) a model for predicting the leakage from indications which may leak more than predicted by the free span model as a result of the crack opening up to the limits of the tube-to-TSP gap (i.e., SG tube leakage from IRBs).

The free span leakage model methodology proposed by the licensee for use at Byron, Unit 1, and Braidwood, Unit 1, have previously been reviewed and approved by the staff as documented in License Amendment No. 54, issued for Braidwood, Unit 1, on August 18, 1994. The methodology documented in the SE issued with this license amendment is consistent with the methodology in GL 95-05. The modifications to this methodology to account for IRBs is discussed below.

The licensee has proposed the following methodology for predicting leakage from IRBs under postulated accident conditions:

(a) Determine the EOC voltage distribution for the indications to which the locked TSP model will be applied in accordance with GL 95-05.

(b) Determine the free span burst pressure for one of the ODSCC indications to which the locked TSP model applies (i.e., primarily hot-leg intersections).

(c) If the ODSCC indication in Item (b) above has a free span burst pressure below the MSLB differential pressure inside the SG tube (i.e., 2560 psi), a bounding IRB leak rate is assigned for this indication. The bounding IRB leak rate is discussed below.

(d) If the ODSCC indication in Item (b) above is determined not to burst under MSLB conditions (i.e., the SG tube burst pressure is greater than the differential pressure inside the SG tube during a postulated MSLB), the free span leakage methodology discussed in GL 95-05 is followed.

(e) Items (b), (c), and (d) above are repeated for all ODSCC indications in the EOC distribution to which the locked TSP model applies. The leakage for all of these ODSCC indications is then summed to determine the total SG leak rate for ODSCC indications to which the locked TSP model is applied.

(f) Items (b) through (e) above are repeated many times (e.g., greater than 100,000) and the leakage values are ordered.

(g) For ODSCC indications to which the free span model is applied, the methodology is identical to that specified above (i.e., Items (a) through (f)) except that all indications are assumed to be in the SG tube free span (i.e., IRBs do not exist) and the determination of the SG tube burst pressure for the ODSCC indications is not necessary for the SG tube leakage calculation. This methodology is consistent with that in GL 95-05.

(h) In accordance with GL 95-05, the 95% confidence bound on the 95th percentile of the total leakage values is determined from the distribution of the SG tube leak rates obtained for the locked TSP model (i.e., Item (f)) and for the free span model (i.e., Item (g)). These two leakage values are summed, and the resultant leakage value is evaluated for acceptable dose consequences as discussed in Section 4.6.

To determine the leakage from an IRB, the licensee performed a detailed test program which is described in its submittal dated August 25, 1995. In this test program, IRBs were simulated and the corresponding SG tube leakage rates were determined. The IRBs were tested inside a simulated TSP and the ODSCC indication was positioned so that 0.10 inches of the indication was outside the collar simulating a TSP. This offset of 0.10 inches corresponds to the maximum expected TSP displacement at any TSP. The licensee determined that the bounding IRB leakage value is on the order of 6.0 gallons per minute (gpm).

The test program implemented by the licensee was intended to conservatively bound the leakage from an IRB. For example, several of the specimens were nearly entirely through-wall with a length near that of the TSP thickness (i.e., 0.75 inches), several of these specimens were positioned such that 0.10 inches of the through-wall portion of the crack extended outside the TSP collar, and the tube-to-TSP diametral gap was near the upper 95% confidence bound for the TSP diametral gaps. The staff concludes that for implementation of the voltage-based SG tube repair criteria proposed by ComEd for Cycle 6 at Braidwood, Unit 1, and for the remainder of Cycle 7 and all of Cycle 8 at Byron, Unit 1, the 6.0 gpm leak rate for an IRB is acceptable, based on the conservatisms in the determination of this value and based on field experience which currently indicates that ODSCC indications of such severity (i.e., very high bobbin voltages) do not typically occur. However, the staff is still evaluating the acceptability of the 6.0 gpm value for long-term implementation. The staff's review will determine if additional conservatisms should be applied so as to raise this 6.0 gpm estimate or whether additional testing is required based on: (1) the potential for the severity of the ODSCC degradation at the TSPs to increase over the long-term (e.g., multiple through-wall cracks occurring near the edges of the TSPs); (2) the staff's continuing review of the SG tube leakage adjustment procedure to MSLB conditions; (3) apparent anomalies in some of the test data; and (4) a review of the final industry (i.e., EPRI) report on this topic.

The staff has evaluated the licensee's proposed methodology for determining the total leak rate from ODSCC indications at the TSP elevations by summing the contributions of the leakage values from the locked TSP model and from the free span model. The staff concludes that this is acceptable for the limited operating cycles at Byron, Unit 1, and Braidwood, Unit 1, for which this repair criteria will be applied, given the limited number and severity of ODSCC indications to which the free span methodology has historically been applied (i.e., primarily cold-leg intersections and intersections adjacent to dented TSP intersections). However, the staff is still evaluating the need for a long-term approach to combine the SG tube leakage estimates from the free span model and the locked TSP model, including a contribution from ODSCC indications which could burst when using the free span model, prior to ordering the total leakage values. The total SG leak rate would then be determined by evaluating the ordered array of the SG tube leak rates at the 95th quantile at a 95% confidence level.

4.5.6 <u>Overall Conclusions Regarding Steam Generator Tube Integrity</u>

Based on the above evaluation, the staff concludes that acceptable structural and leakage integrity of the ODSCC indications accepted for continued service under the voltage-based SG tube repair criteria proposed by ComEd in its letter dated September 1, 1995, can be ensured at Braidwood, Unit 1, and Byron, Unit 1, for one cycle of operation at Braidwood, Unit 1, and one and one half cycles at Byron, Unit 1, as discussed above, consistent with applicable regulatory requirements. The staff's acceptance of the proposed voltage-based repair criteria is based, in part, on the licensee being able to demonstrate that the conditional probability of burst and the primary-to-secondary leakage during a postulated MSLB will be acceptable. It is also based on the licensee being able to provide reasonable assurance of the structural integrity of the load path components as discussed above in Section 4.1.3 of this SE.

The staff notes that additional areas will need to be addressed prior to approving this repair criteria on a long-term basis. These areas include, but are not necessarily limited to:

(a) The long-term integrity of the SG internals including the TSPs.

(b) The long-term integrity of the expanded tubes as discussed in Section 4.5.2 of this SE.

(c) Combining of the probability of axial and axial tensile SG tube burst for both the free span and locked TSP model as discussed in Section 4.5.3.2.3 of this SE.

(d) The long-term acceptability of the IRB leakage estimate as discussed in Section 4.5.4.2 of this SE.

(e) The criteria for assessing the significance of dented intersections at SG tubes adjacent to the expanded tubes.

(f) The reporting requirements including those contained in the TSs.

(i) The methodology for combining the SG tube leakage estimates from the free span and locked TSP leakage models as discussed in Section 4.5.4.2 of this SE.

(j) The effects on the SG tube burst pressure of multiple indications extending 0.10 inches outside the TSPs as discussed in Sections 4.5.3.1.1.c and 4.5.3.2.3 in this SE.

4.6 Radiological Consequences

In the SE issued with License Amendment No. 54, dated August 18, 1994, the staff evaluated the radiological dose consequences of a postulated MSLB at the end of Cycle 5 for Braidwood, Unit 1, assuming a primary-to-secondary SG tube leakage of 9.1 gallons per minute (gpm) which was the licensee's limiting value in its TSs. The dose equivalent concentration of iodine-131 in the reactor coolant in this prior evaluation was assumed to be at the maximum value allowed in the then current Braidwood, Unit 1, TSs (i.e., 0.35 microcuries per gram of coolant). The value of the two-hour thyroid dose at Braidwood's exclusion area boundary (EAB) was calculated by the staff using the assumptions listed in Section 3.5 of the SE cited above, as 4 rem for the event-generated iodine spike case as shown in Table 1 of this prior evaluation.

The licensee proposed in its request for license amendments dated September 1, 1995, to maintain the present TS value of the maximum permissible primary coolant concentration of iodine-131 as 0.35 microcuries per gram of coolant for the forthcoming fuel cycles. The licensee also stated that its site allowable primary-to-secondary SG tube leakage was 26.8 gpm for Braidwood, Unit 1. This site specific leakage rate proposed by ComEd would thereby result in a two-hour EAB thyroid dose of about 12 rem, assuming the maximum allowable TS value of the dose equivalent concentration of iodine-131. In that this estimated radiation dose to the thyroid and the relatively small whole-body radiation exposure (i.e., less than 0.3 rem) are still small fractions of the exposure guideline values of 10 CFR Part 100, we find that the proposed Braidwood site specific allowable primary-to-secondary SG tube leakage of 26.8 gpm, is acceptable. This conclusion is based on the estimated radiation exposure doses being lower than the staff's acceptance criteria for radiation exposure of 30 rem to the thyroid and 2.5 rem for whole-body exposure as shown in Table 1 of the prior evaluation cited above.

The licensee proposed reducing the maximum allowable dose equivalent iodine-131 concentration in the Byron, Unit 1, TSs from 1.0 to 0.35 microcuries per gram of reactor coolant, the same value cited above for the Braidwood, Unit 1, primary coolant. The staff's estimate of the two hour EAB thyroid dose for the licensee's proposed Byron site specific primary-to-secondary SG leakage of 36.5 gpm, is 12.1 rem. This estimate is based on the staff's prior evaluation in Section 4.5 of the SE issued with the Byron, Unit 1, License Amendment No. 66, dated October 24, 1994, and is the same as previously estimated in the SE dated October 24, 1994, in that the licensee increased its proposed Byron, Unit 1, site specific SG tube leakage to reflect the decrease in its proposed iodine-131 primary coolant concentration. As in the case of Braidwood, Unit 1, the whole-body dose remains well below the acceptance criteria of 2.5 rem. The staff finds that the licensee's proposed Byron site specific leakage rate of 36.5 gpm is acceptable. This conclusion is based on the estimated radiation exposure doses being lower than the staff's acceptance criteria cited above.

Based on the foregoing considerations, the staff concludes that the radiological consequences outside containment for a postulated MSLB for Byron, Unit 1, and Braidwood, Unit 1, are acceptable, based on the projected primary-to-secondary SG tube leakage rate not exceeding 26.8 gpm at Braidwood, Unit 1, at the end of Cycle 6 and not exceeding 36.5 gpm at Byron, Unit 1, over the remainder of Cycle 7 and at the end of Cycle 8.

We also agree with the licensee that its adoption of a maximum permissible dose equivalent iodine-131 concentration of 0.35 microcuries per gram of primary coolant in the Byron, Unit 1, and Braidwood, Unit 1, TSs, is a significant defense-in-depth approach. The net effect of proposing this maximum permissible concentration of iodine-131 at this level in the Byron, Unit 1, and Braidwood, Unit 1, TSs for the forthcoming fuel cycles, is to reduce the potential radiation exposure outside containment by about a factor of 3 in the event of an MSLB.

5.0 APPROVAL OF TECHNICAL SPECIFICATION REVISIONS

The proposed changes to TS Section 4.4.5.2 are acceptable in that they incorporate added surveillance requirements for the SGs into the TSs for Byron, Unit 1, and Braidwood, Unit 1, which are important elements of the inspection guidelines for implementing the voltage-based SG tube repair criteria as contained in Generic Letter 95-05. Specifically, these surveillance requirements establish the need to inspect all ODSCC flaws left in service as a consequence of implementing the voltage repair limits proposed in the licensee's request for license amendments dated September 1,1995. These proposed surveillance requirements also specify which of the TSP intersections must be inspected with a bobbin coil. Furthermore, the proposed revision of TS Section 4.4.5.2.d in the Braidwood, Unit 1, TSs limits the application of the revised voltage repair limits for one cycle (i.e., Cycle 6) while the revision of TS Section 4.4.5.2.d in the Byron, Unit 1, TS limits the application of the revised voltage repair criteria for one and a half cycles (i.e., the remainder of Cycle 7 and all of Cycle 8). This limitation on the length of applicability of the revised voltage repair criteria to one cycle for Braidwood, Unit 1, and one and a half cycles for Byron, Unit 1, is to allow the licensee and the staff the opportunity to evaluate the applicability of the licensee's revised methodology as discussed in Section 4 of this Safety Evaluation (SE) for long-term usage (i.e., for more than one cycle between inspections) for the repair of ODSCC flaws. In a similar manner, the revision to the surveillance requirements in TS Section 4.4.5.3 of the Byron, Unit 1, and Braidwood TSs are acceptable in that they also limit the application of the revised voltage repair as discussed above.

The proposed changes to TS Section 4.4.5.4.a.11 of the Byron, Unit 1, and Braidwood, Unit 1, TSs are acceptable in that they reflect the voltage repair criteria derived from the methodology reviewed and found acceptable by the staff in Section 4 of this SE for the disposition of SG tube flaws identified as ODSCC at the hot-leg SG tube intersections with the tube support plates (TSPs). The disposition of ODSCC flaws on the cold-leg side of the SGs is also incorporated into these same TS sections. We find these latter proposed revisions acceptable on the basis that these cold-leg voltage repair limits are consistent with the staff's guidance in GL 95-05.

The proposed changes to TS Section 4.4.5.5.d are acceptable in that they implement the reporting requirements reviewed and found acceptable by the staff in Section 4 of this SE.

The proposed revision to TS Section 3.4.8 of the Braidwood, Unit 1, TSs is acceptable in that this revision extends the same value of the maximum permissible dose equivalent iodine-131 concentration in the reactor coolant (i.e., 0.35 microcuries per gram) from the last operating cycle into all forthcoming fuel cycles. By reducing this concentration from the prior value of 1.0 microcuries per gram, the licensee is thereby reducing the radiological dose consequences to the public by a factor of about 3 in the event of a main steamline break (MSLB) as discussed in Section 4.6 of this SE. By reducing the maximum permissible dose equivalent iodine-131 concentration in the reactor coolant from 1.0 to 0.35 microcuries per gram as proposed in TS 3.4.8 of the Byron, Unit 1, TSs, a similar reduction in the radiological dose consequences at the Byron, Unit 1, exclusion area boundary is achieved. These reductions in the iodine-131 concentration are reflected in the proposed revisions to Table 4.4-4 of the Byron, Unit 1, and Braidwood, Unit 1, TSs. These proposed changes to TS Section 3.4.8 and Table 4.4-4 in both the Byron, Unit 1, and Braidwood, Unit 1, TSs are acceptable in that they reduce potential radiological exposure to the public.

The proposed revisions to the Bases TS Sections B 3/4.4.5 in the Byron, Unit 1, and Braidwood, Unit 1, TSs are acceptable in that they provide a concise discussion of the methodology used by the licensee to develop the voltage-based SG tube repair criteria which they have proposed for the hot-leg and the cold-leg sides of the Byron, Unit 1, and Braidwood, Unit 1, Model D4 SGs. This discussion also provides a reference (i.e., WCAP-14273) to a more detailed presentation of ComEd's methodology for voltage repair limits which have been reviewed and accepted by the staff for a limited application at Byron, Unit 1, and Braidwood, Unit 1 (i.e., Cycle 6 at Braidwood, Unit 1, and through Cycle 8 at Byron, Unit 1).

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.

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. 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 (60 FR 49963). 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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Date: November 9, 1995

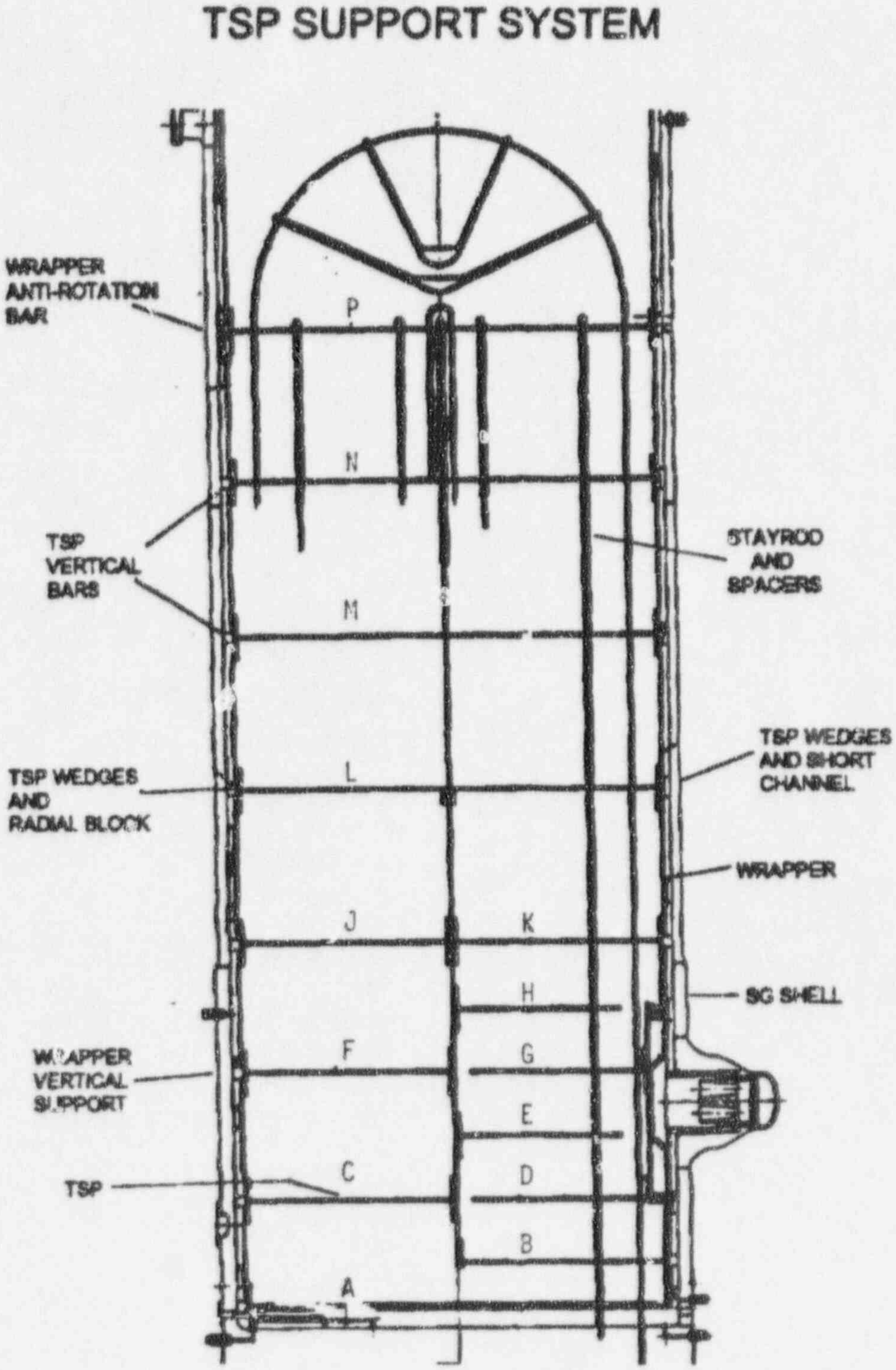

Figure 1

SCHEMATIC REPRESENTATION OF THE WESTINGHOUSE MODEL D4 STEAM GENERATOR