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Title Diablo Canyon Unit 2 - 2R9 Voltage-Based Repair Criteria 90 Day Report

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PURPOSE AND SUMMARY OF RESULTS:

This report provides the results of the Diablo Canyon Unit 2 October 1999 Outage (2R9) with respect to (1) the eddy current inspection of the steam generator tubes at TSP intersections and (2) the implementation of the Alternate Repair Criteria (ARC) as specified in Generic Letter 95-05 for ODSCC at TSP intersections in Westinghouse-designed steam generators with drilled supports and alloy 600 tubing. This summary also provides the projected EOC-10 probability of burst and leak rate tube integrity calculations as required for ARC implementation.

Note that the proprietary version of this report is contained in Ref. 15.

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00		Initial release
01		Customer editorial comments

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Glossary of Acronyms

Term	Definition
AONDB	Axial ODSCC Not Detected by Bobbin
ARC	Alternate Repair Criteria
BOC	Beginning of Cycle
CPDF	Cumulative Probability Distribution Function
CFR	Code of Federal Regulations
CLT	Cold-Leg Thinning
DCPP	Diablo Canyon Power Plant
DIS	Distorted ID Support Signal with possible Indication
DOS	Distorted OD Support Signal with possible Indication
DNF	Degradation Not Found
EFPD	Effective Full Power Day
EFPY	Effective Full Power Year
ECT	Eddy Current Test
EOC	End of Cycle
FS	Free Span
FTI	Framatome Technologies, Inc.
GL	NRC Generic Letter 95-05
GPM	Gallons per Minute
ISI	In-service Inspection
MSLB	Main Steam Line Break
NDE	Non Destructive Examination
NDD	No Degradation Detected
NRC	Nuclear Regulatory Commission
ODSCC	Outside Diameter Stress Corrosion Cracking
PG&E	Pacific Gas and Electric Company
POB	Probability of Burst
POD	Probability of Detection
POPCD	Probability of Prior Cycle Detection
POL	Probability of Leak
PWSCC	Primary Water Stress Corrosion Cracking
RPC	Rotating Pancake Coil
RSS	Retest Support Plate Signal
RTS	Return to Service
SG	Steam Generator
SER	Safety Evaluation Report
TS	Technical Specification
TSP	Tube Support Plate
WEXTEX	Westinghouse Explosive Tubesheet Expansion
+Point	Plus Point Coil

1.0 Introduction

The Diablo Canyon Power Plant (DCPP) Unit 2 completed the ninth cycle of operation and subsequent steam generator ISI in October of 1999. The unit employs four Westinghouse-designed Model 51 SGs with 7/8-inch OD mill annealed alloy 600 tubing and ¾-inch carbon steel drilled-hole tube support plates.

Axial ODSCC has been confirmed within the TSP regions of the steam generators and is a current degradation mechanism at both DCPP units. The NRC Generic Letter 95-05, Ref. 1, outlines an alternate repair criteria (ARC) for allowing tubes containing ODSCC indications to remain in service if the indications are contained within the TSP structure and the measured Bobbin voltage is ≤2.0 volts. A complete list of exclusion criteria is provided in section 1.b of Ref. 1 and in Ref. 2. The NRC has approved implementation of the voltage-based repair criteria at both DCPP units per Ref. 2. It should be noted that this ninth refueling outage (EOC-9) is the second implementation of the voltage-based repair criteria at Unit 2 and the third overall at DCPP. The eighth refueling outage at Unit 2 (2R8) was the first implementation of the ARC.

In accordance with the Generic Letter 95-05, ARC implementation requires a pre-startup assessment (Ref. 3) and a 90 day post-startup tube integrity assessment. The reports are specific to support-plate ODSCC and are similar to probabilistic condition monitoring and operational assessments, respectively. Each assessment must include calculated conditional probability of burst and calculated leak rate during a postulated MSLB with the 90 day report providing a more detailed account of the inspection relative to the ARC and addressing the projected growth of degradation over the next operating cycle.

Framatome Technologies, Inc. (FTI) uses Monte Carlo codes, as described in Refs. 4 and 5, to provide the burst and leak rate analysis simulations. These codes are based on the methods in Ref. 6. The inputs for this analysis include the EOC (as-found) Bobbin voltage distributions adjusted with the NRC-approved probability of detection, repaired tubes, tubes returned to service, measurement uncertainties, and combined active and deplugged tube voltage growth rate distributions. The analysis outputs project EOC Bobbin voltage distributions and the resulting probability of burst and leak rate. The correlation parameters used in the simulation are taken from the EPRI ODSCC ARC Addendum 3 Updated Database (Ref. 7) as reviewed in Section 5 of this report. This reference contains the latest updated correlations of Bobbin voltage to burst pressure, leak rate, and probability of leakage. It should be noted that the leak rate correlation was not included in Ref. 7 since it was not changed.

During a post-outage review of U2R9, it was discovered that two Bobbin retest inspections were inadvertently missed during the outage. The tube locations were R4C46 and R36C48 both in SG 2-4. Ref. 1 and the plant analysis procedures for EOC-9 (Ref. 8) required all DOS indications greater than or equal to 1.5 volts and inspected with a worn or "ARC Out" probe to be re-inspected full length with a good or "ARC In" probe. An FTI NCR (nonconformance report) #99-00653 (Ref. 16) was written to disposition these missed retest inspections as "Use as is". Section 3.8 of this report addresses the resolution of this NCR in more detail.

This ARC 90-Day Report provides a detailed summary of the Bobbin and RPC (+Point) probe inspection results as well as the probabilistic burst and leak results for the projected EOC-10 voltage distributions. As prescribed in Section 6.b of Generic Letter 95-05, this 90-Day Report provides, at a minimum, the following information:

- EOC-9 voltage distributions of all indications found during 2R9 (Tables 4-1 through 4-4 and Figures 4-1 through 4-4).
- Cycle 9 voltage growth rate distributions with comparisons to the industry average rate (Tables 4-5 and 4-6 and Figures 4-11 through 4-14).
- Cycle 10 voltage combined active and deplugged tube growth rate distributions (Tables 4-10 through 4-14 and Figure 4-14).
- EOC-9 voltage distribution of repaired indications (Tables 4-1 through 4-4 and Figures 4-5 and 4-6).
- Voltage distribution for indications left in service at BOC-10 confirmed or not inspected by Plus Point (Tables 4-1 through 4-4 and Figures 4-7 and 4-8).
- Voltage distribution for all DOS indications left in service at BOC-10 (Tables 4-1 through 4-4 and Figures 4-9 and 4-10).
- NDE examination uncertainty distribution used in predicting the EOC-10 voltage distribution (Table 4-7 and Figure 4-15).
- Projected EOC-10 voltage distributions (Table 4-8 and Figures 4-16 through 4-19).
- Results of tube integrity calculations for probability of burst and leak rate at MLSB conditions at the EOC-10 including the correlations that were used (Sections 5 and 7).

This report also includes certain reviews of probe wear issues that were additionally addressed by Ref. 12. Those requirements include a comparison of actual versus projected EOC-9 voltages (Figures 3-3 through 3-6), a review of indications greater than 0.5 volts that were inspected with a worn probe in the previous outage (Table 3-8), a review of the proportionality of new indications that were inspected with a worn probe in the previous outage (Table 3-8), and a review of the adequacy of the 75 percent criteria per Ref. 12.

The 2R9 scope of eddy current inspections at DCPP Unit 2 included a 100% full-length Bobbin coil inspection of all four steam generators. A detailed description of the inspection scope and results is provided in Section 3 of this report. Section 4 reviews the Bobbin voltage distributions and associated growth distributions. Sections 5 and 7 include a discussion of the correlations used (Ref. 7) and the tube integrity assessments and calculations to confirm that steam generator tubing will retain adequate margin to structural and leakage integrity through to the next scheduled outage. Section 6 includes an evaluation of POPCD for EOC-8.

As noted earlier, ARC implementation also requires completion of preliminary burst and leak rate analyses as a basis to justify plant restart. For DCPP Unit 2, this analysis (Ref. 3) was similar to a condition monitoring assessment and used actual "as-found" EOC-9 Bobbin voltages, adjusted for NDE uncertainty. This "alternative" tube integrity calculation is allowed per section 2.c of Generic Letter 95-05 (Ref. 1). The analyses concluded that the as-found probability of burst and conditional leak rates for EOC-9 were well within allowable limits.

2.0 Executive Summary

ODSCC at tube-to-TSP intersections is a current damage mechanism at DCPP Units 1 and 2 based on Ref. 8. Since 1993 (2R5), 100% of SG tubes have been inspected with Bobbin probes each refueling cycle and a continuously augmented inspection program has been implemented to inspect dented intersections with Plus Point. The current Plus Point dent inspection methodology requires, on a SG basis, 100% of dents up to the highest support intersection where PWSCC had previously been detected, plus 20% at the next highest TSP elevation. In some instances, PWSCC has occurred in conjunction with ODSCC at an intersection. The associated OD indication may be applicable for inclusion in the ARC calculations but the tube would be repaired by plugging per Ref. 2.

NRC approval for implementation of the voltage-based ARC was obtained in the prior Unit 2 refueling outage (2R8). The approval however was received late, i.e., during the course of the 2R8 eddy current inspections. As such, all OD distorted support signals (called OD-DSS) were inspected with Plus Point. In 2R9 DOS indications less than 2 volts were generally not inspected with Plus Point unless an inspection was performed in association with a dent or an exclusion criterion (Ref. 9).

In 2R8, requirements in regard to Bobbin probe wear monitoring and voltage normalization of calibration standards were carried out in accordance with Generic Letter 95-05. Accordingly, assessments of probe wear must be completed in 2R9 and subsequent outages to review the effectiveness of the 15% tolerance criteria for wear and the adequacy of the 75% voltage criteria for re-inspection. This review is conducted in Section 3.8.

A total of 559 Bobbin coil distorted outside diameter (OD) support signal (DOS) indications were detected at TSP intersections during the Unit 2R9 ISI. 78 of this total were from 69 tubes that were deplugged to be returned to service. 148 DOS indications were inspected with Plus Point and 115 of those confirmed as axially oriented ODSCC. All of the deplugged DOSs were inspected with Plus Point. 411 DOS indications (about 74 percent) were not required to be inspected with Plus Point per Refs. 2 and 8. The total number of DOS indications in the Monte Carlo distributions was 563, which includes the addition of 10 indications that were AONDB (axial ODSCC not detected by Bobbin). Two DOSs that confirmed as SVI and four DOSs that were located in the cold leg thinning (CLT) region were not included in the Monte Carlo analysis. Of the 563 indications, 60 were greater than or equal to 1.0 volt by Bobbin coil, and 8 indications were detected at voltages greater than the 2.0 volt lower repair limit (LRL). There were no indications detected that exceeded the upper repair limit of 5.1 volts (Ref. 9). Of the 26 DOS indications removed from service during 2R9, 22 were directly attributed to confirmed ODSCC. The remaining 4 were not repairable but had repairable indications at another location within that tube. No tubes were pulled during 2R9.

The overall 2R9 average Bobbin voltage including deplugged tubes was found to be 0.59 volts, and the voltage range extended from a low of 0.10 to a high of 3.02 volts. The 2R9 average voltage for inservice tubes was found to be 0.56 volts, slightly higher than that found in 2R8, 0.46 volts. The trend is expected since more indications are being left in service. The voltage range for the 2R9 in-service tubes ranged from a low of 0.14 to a high of 2.89 volts and the deplugged tube range was from 0.10 to a high of 3.02 volts.

The average growth rate for Unit 2 Cycle 9 was 0.196 volts for tubes in service during the cycle. This growth is equivalent to 0.134 volts or 35.6% per EFPY. The growth rate exceeds the recommended minimum 30% per EFPY specified in the Generic Letter 95-05 for the upper repair limit calculation. The measured growth rates have been trending upward. The Unit 2 Cycle 8 growth rate was 0.051 volts or 13.3% per EFPY. The projected growth for Cycle 10, therefore, will be 35.6 x (1.44 EFPY) or 51.3%, and the upper repair limit for 2R10 would then be reduced to 4.8 volts, assuming a structural limit of 8.3 volts.

During 2R9, 138 previously plugged tubes were deplugged and re-inspected. These tubes were plugged during recent outages after and including 2R5. The tubes were plugged for various damage mechanisms including WEXTEX PWSCC, support plate PWSCC and support plate ODSCC. From this group of tubes, 67 tubes, primarily from 2R7, were deplugged for recoverable support plate ODSCC.

The BOC-10 voltage distributions for input into the Monte Carlo simulations were determined by applying the NRC-mandated probability of detection (POD) of 0.6 to the as found DOS population, subtracting the repaired tube indications, and then adding the deplugged tube indications returned to service for each steam generator.

The growth rate to be used for Cycle 10 consists of two components, i.e., active and deplugged tube growth, which are combined per Ref. 18. This is because no prior cycle growth rate exists for the tubes deplugged in U2R9. The growth for the deplugged tube component will be based upon the industry limiting first cycle growth for deplugged tubes per Table 8-5 of Ref. 18. Per Ref. 18, this very conservative growth distribution is suggested for the first cycle of operation for deplugged tubes. Cycle 10 will be the first cycle of operation with deplugged tubes containing support plate ODSCC at DCPP-2.

Since more than 200 indications were found in active tubes for Cycle 9, generator composite or generator-specific growth can be used rather than the industry-bounding growth curve for the active tube population growth component.

These two growth rates (i.e., active and deplugged) were combined per the Ref. 18 formulations to calculate the projected Cycle 10 growth rate distribution for input into the Monte Carlo simulation. For each generator, a generator-specific or composite generator growth rate for active tubes and the conservative growth distribution for deplugged tubes were combined based on the number of indications of each type being returned to service. This combined growth distribution along with the respective BOC-10 voltage distribution for each generator provided the basis for each burst, POL, and leak rate analysis.

The probability of burst and leak rate input parameters were based on the latest 1999 updated ARC database. Conditional MSLB leak rate and tube burst probabilities were calculated for the projected population of indications at the end of Cycle 10 using 1 million simulations. The calculated results meet the NRC probability of burst limit of $1x10^{-2}$, and the DCPP Unit 2-specific primary-to-secondary leak rate limit of 12.8 gpm (Ref. 9). SG 2-4 had the limiting results for EOC-10, i.e., a probability of burst of 3.24×10^{-4}. SG 2-4 also had the limiting EOC-10 projected leak rate of 1.245 gpm (at room temperature). Both results are well within the allowable limits.

3.0 DCPP-2 EOC-9 Inspection Results and Voltage Growth Rates

Since tubes were deplugged during 2R9, this section addresses deplugged and active tubes separately and then gives an overall summary of the inspections in Section 3.5.

3.1 Inspections for Inservice Tubes

The 2R9 Bobbin coil inspection consisted of a 100% full-length Bobbin coil examination of tubes in all four steam generators except for the U-bends of rows 1 and 2, which were inspected with a single coil +Point probe. A 0.720 inch diameter Bobbin probe was used for the full-length examinations including all TSP intersections in the hot and cold legs. Probe designs used included those with changeable centering feet, which in addition to probe wear monitoring required signal-to-noise tracking per Refs. 8 and 11.

During 2R9, RPC (Plus Point) examination of TSP intersections was conducted as follows in the support of the voltage-based ARC.

- 100% of DOSs greater than or equal to 2 volts.
- 100% of DOSs at dented intersections.
- 100% of DISs.
- 100% of DOSs in intersections excluded from the ARC (i.e., intersections with mix residual signals exceeding a voltage threshold that could mask a 1.0 volt Bobbin DOS signal, intersections with suspected TSP ligament cracking, intersections in the wedge regions or 7th TSP bending region, indications that may extend outside the TSP crevice, intersections that contain PWSCC or circumferential indications, and intersections that may have interfering signals from copper).
- 100% of greater than or equal to 5 volt dent intersections.
- 100% of less than 5 volt dented intersections up to the highest TSP elevation where PWSCC has been previously detected in that specific steam generator, plus 20% of dents at the next highest TSP elevation. For 2R9, this translated into the following initial scope inspections:

    1. SG 2-1: 20% at 1H.
    2. SG 2-2: 100% from 1H to 5H, plus 20% at 6H.
    3. SG 2-3 and SG 2-4: 100% from 1H to 3H, plus 20% at 4H.

In SG 2-1, the dent scope was expanded during the outage to include 100% of dented intersections from 1H to 2H, plus 20% at 3H, because axial ODSCC not detectable by bobbin (AONDB) was found by Plus Point at a 2H dented intersection.

3.2 Inspection Results for In-service Tubes

The results of the inspections with respect to the ARC were as follows:

(1) A total of 481 intersections with distorted OD-type support plate signals (DOSs) were identified in all four steam generators for the tubes that were inservice during Cycle 9. 469 of the DOSs were located in the hot leg and 12 were located in the cold leg.

(2) Of the 12 cold-leg DOS indications, none confirmed as crack-like. 6 were located in the cold-leg thinning (CLT) regions (i.e., at an expanded periphery and at the 1C, 2C, 3C or 4C intersections). These 6 indications are considered attributable to cold leg thinning and were not included in the DOS analysis pool for the BOC-10 distribution. In addition, two of the 6 DOSs located in the CLT region confirmed as OD-initiated volumetric indications (SVIs). These tubes, one in SG 2-1 and one in SG 2-3, were repaired by plugging. The overall breakdown for DOS indications located in the CLT region was: 1 in SG 2-1, 1 in SG 2-2, 2 in SG 2-3, and 2 in SG 2-4. The remaining six cold-leg DOSs were included in the BOC-10 distribution.

(3) 6 DOS indications greater than the LRL (2.0 volts) were found in active tubes. Each of the indications confirmed as ODSCC. These indications, one in SG 22, one in SG 23, and four in SG 24, required repair by plugging.

(4) 10 AONDB (axial ODSCC not detected by Bobbin) indications were found by Plus Point. Four of these indications were located in SG21, two in SG 22, and four were located in SG 24. These indications were determined to be ODSCC by Plus Point but had no associated DOS call by Bobbin. Nine of the intersections had DNT calls made with associated OD phase angles, and the one that was not dented had a support plate residual (SPR) signal. Denting masks the signal voltages for these indications such that the DOS Bobbin voltages are unobtainable. One of the AONDB indications had a DNT greater than 5 volts that required repair by plugging. Since there were no DOS voltages for these indications, Bobbin voltages were calculated using the methodology in Section 8.1 of Ref. 7. This method allowed these 10 indications to be included in the BOC-10 Bobbin distribution population and 9 to remain in service per Ref. 19. These indications however are not included in the growth distributions since the 2R8 voltages are zero. A summary of the correlation results used to calculate the Bobbin voltages based on the Plus Point voltage and the justification are discussed further in Section 3.9. Table 3-11 shows a listing of those indications along with the assigned Bobbin voltages. All of the assigned Bobbin voltages were less than 2 volts.

(5) 78 DISs were identified during the Bobbin exam. These tube intersections exhibit ID signals by Bobbin and may confirm as PWSCC when inspected with Plus Point. 8 were found in SG 21, 50 in SG 22, 4 in SG 23, and 16 in SG 24. All of the DIS indications have associated DNT calls at the same intersection. The dispositioning of confirmed axial PWSCC indications are not addressed by the voltage-based ARC since the signals are not OD-initiated (Refs. 2 and 9).

(6) 5 circumferential ODSCC indications were found at TSPs. The circumferential indications were all dented and were detected by Plus Point during the > 5.0 volt dent inspections. There were no DOS indications associated with these circumferential calls. These indications were repaired by plugging and are not applicable to the ARC. Also, no DOS indications were found containing component OD/ID flaws at the same TSP location.

(7) Overall, 24 DOS indications from 22 in-service tubes were repaired. This total includes 5 tubes in SG 22, 2 in SG23, and 15 in SG 24.

Since 6 DOS calls in the CLT zone were excluded, and 10 AONDB indications were added, the total number of DOSs to be analyzed in active tubes increased from 481 to 485 indications. The overall breakdown of DOS indications in the active tube population was as follows: 99 in SG 2-1, 58 in SG 2-2, 52 in SG 2-3, and 276 in SG 2-4, totaling 485 indications. The 2R9 average voltage was 0.56 volts for in-service tubes. This is slightly higher than the prior 2R8 outage average of 0.46 volts. The 2R9 average is expected to be higher than 2R8 since this is the second implementation of the ARC at Unit 2 (i.e., confirmed indications were left in service). The 2R9 voltage range extended from a low of 0.14 to a high of 2.89 volts (in SG 2-2).

An upper voltage repair limit (URL) must be calculated prior to each eddy current inspection. This is the voltage value, above which, DOS indications no longer qualify for the ARC (i.e., must be plugged regardless of Plus Point confirmation). No indications were found approaching the URL, which was determined to be 5.1 volts based on the 2R8 average growth. This calculation is discussed in further detail in Section 3.7.

The lower repair limit of 2.0 volts is based on Ref. 1, and this voltage was exceeded by 6 indications in active tubes. The Bobbin and associated Plus Point results for these indications are shown in the Table 3-1.

For information, all of the DOS voltages found above 1.0 volts are shown in Table 3-3. Tables 4-1 through 4-4 contain the as-found voltage distribution of DOSs identified during the Bobbin coil inspection for each steam generator. Note that these tables also show deplugged tube indications.

3.3 Plus Point Confirmation Results (Inservice tubes for Cycle 9)

Of the 485 DOS indications, 74 (14 in SG 2-1, 19 in SG 2-2, 9 in SG 2-3, and 32 in SG 2-4) were inspected with Plus Point. 52 of these indications were confirmed as axial ODSCC, resulting in a confirmation rate of about 70% for those inspected. 30 of the confirmed calls were also located at dented intersections. The breakdown for ODSCC indications at dented intersections included: 8 in SG 2-1, 11 in SG 2-2, 2 in SG 2-3, and 9 in SG 2-4.

Of the 52 confirmed axial ODSCC indications, 21 were removed from service for reasons explained in Section 3.5. The DCPP acceptance criteria for confirmed axial ODSCC, based on Ref. 9, includes: (a) DOS voltage less than or equal to 2 volts, (b) dent voltage less than 5 volts,

(c) no associated PWSCC, (d) location within the bounds of the TSP, (e) no circumferential extents, (f) no TSP ligament gaps, (g) no AONDB with greater than 5 volt dent, (h) not located in a wedge exclusion zone or 7th TSP bending exclusion zone, and (i) no mix residual that could mask a 1 volt bobbin flaw. Plus Point confirmed ODSCC not meeting these acceptance criteria were plugged.

A total of 31 confirmed axial ODSCC indications, in 31 tubes, were saved from plugging by use of the ARC. The distribution was 8 tubes in SG 2-1, 9 tubes in SG 2-2, 4 tubes in SG 2-3, and 10 tubes in SG 2-4. If the tubes not inspected by Plus Point are considered and the confirmation rates are applied at 60% conservatively, approximately 51 tubes in SG 2-1, 22 tubes in SG 2-2, 26 tubes in SG 2-3, and 124 tubes in SG 2-4 were additionally saved by ARC implementation, a total of 223 more tubes. The projected grand total would then be about 254 active tubes saved by ARC implementation in the active tube population.

3.4 Inspection Results (Deplugged tubes during 2R9 for Cycle 10)

During 2R9, 138 previously plugged tubes were deplugged and re-inspected. These tubes were plugged during recent outages back to and including 2R5. These tubes were plugged for various damage mechanisms including WEXTEX PWSCC, support plate PWSCC, and support plate ODSCC. From this group of recovered tubes, 67 tubes, primarily from 2R7, were deplugged for ODSCC. 78 DOS calls were made from this group of tubes, 11 in SG 2-1, 7 in SG 2-2, 6 in SG 2-3, and 54 in SG 2-4. Note that Ref. 8 required all DOS indications in deplugged tubes to be inspected with Plus Point regardless of voltage. 73 of the 78 DOSs confirmed as axial ODSCC and 2 of the deplugged tubes (both in SG 2-1) required replugging because the DOS voltages exceeded the LRL.

All of the previous ODSCC intersections re-confirmed as ODSCC by Plus Point. In addition, 10 new DOS indications were found that were not observed in 2R7, and 6 of the new DOSs confirmed as ODSCC. Each had relatively low Bobbin signals, and none were dented. In SG 2-1, there were 2 new DOSs and both confirmed as ODSCC. In SG 2-2, there was 1 new DOS and it did not confirm as ODSCC. There were no new DOSs in SG 2-3, and in SG 2-4, there were 7 new DOSs with 4 confirming as ODSCC.

The average DOS voltage from deplugged tubes was found to be 0.75 volts. This value is compared to an average of 0.56 volts for the tubes in service for Cycle 9, and an average voltage of 0.71 volts for deplugged DOSs from 1R9 (Ref. 17). The 2R9 voltage range for deplugged DOSs extended from a low of 0.10 to a high of 3.02 volts (in SG 2-1).

3.5 Inspection Results Summary

The following provides an overall summary of the 2R9 inspection results for the combined active and deplugged tubes:

- 559 DOSs were identified. 6 in the CLT region were excluded, and 10 AONDB indications were added to the BOC-10 distribution. This resulted in a total of 563 DOS indications for inclusion in the BOC-10 distribution. The overall breakdown was as follows: 110 in SG 2-1, 65 in SG 2-2, 58 in SG 2-3, and 330 in SG 2-4.

- 8 DOS indications exceeded the 2.0 volt repair limit, and were plugged because of Plus Point confirmation. Only 2 of the 8 indications were located in deplugged tubes (see Table 3-2).

- Of the 563 DOS indications, 125 were confirmed by +Point as axial ODSCC, 27 were DNF, and 411 were not inspected.

- 23 confirmed axial ODSCC indications were removed from service during 2R9: 8 repaired for ODSCC with a greater than 2.0 volt DOS, 13 repaired for ODSCC at a wedge intersection, 1 repaired due to circumferential PWSCC indication at another intersection in that tube, and 1 repaired for AONDB with a greater than 5 volt dent. 3 additional non-repairable DOSs were removed from service for mechanisms at other intersections within that tube: 1 for greater than 40% TW CLT at a different intersection, 1 for ODSCC with a greater than 2.0 volt DOS at a different intersection, and 1 for wedge ODSCC at a different intersection. A total of 26 DOS indications were removed from service during 2R9.

- The number of Cycle 9 DOS indications as well as the maximum and average voltages as a function of support plate location are summarized in Tables 3-4 and 3-5, respectively, for the active and deplugged tubes. The data, as in previous reviews, show a strong pre-disposition of ODSCC to occur in the first and second hot-leg TSPs (469 out of the 563 indications occurred at the 1H or 2H intersections), although the mechanism extended to higher TSPs. This distribution indicates the predominant temperature dependence of ODSCC, similar to that observed at other Model 51 plants.

- 5 circumferential ODSCC indications were found at TSPs (all at 1H and all in SG 2-2). Each of these indications had large voltage dents but no detectable DOS voltage. These indications were repaired by plugging and are not applicable to the ARC.

- No axial combination OD/ID flaws were found at TSPs.

- 78 hot-leg DIS indications were called with Bobbin. 17 of the 78 DIS indications were from deplugged tubes. 27 confirmed as axial PWSCC and 2 confirmed as circumferential PWSCC. DIS indications are not candidates for the ARC.

- Based on the number of repaired indications, a total of 537 ARC-applicable DOS indications will be inservice for Cycle 10 operation.

3.6 Voltage Data Review and Voltage Growth

The maximum and average DOS voltages per support plate intersection during Cycle 9 are summarized in Tables 3-4 and 3-5 for active and deplugged tubes, respectively, for each SG. The average voltage found for active tubes was 0.44, 0.48, 0.57, and 0.62 respectively, for SG 2-1, SG 2-2, SG 2-3, and SG 2-4 with the composite average being 0.56 volts. For deplugged tubes, the average voltage was found to be 1.07, 0.43, 0.67, and 0.74 respectively, with the composite average being 0.75 volts.

Of the 485 DOS calls made at 2R9 for tubes in service during Unit 2 Cycle 9, 301 were new DOSs not called in 2R8. Voltage "look ups", therefore, were performed of the 2R8 data to assess voltage growth in support of the ARC. Considering the exclusion of the ten AONDB indications and the 22 indications there were NDD in 2R8 based on "look-ups", 453 indications were available to be included in the Cycle 9 growth distribution from the active tube population. In accordance with the requirements of Generic Letter 95-05, voltage growth rates were only evaluated for those intersections at which Bobbin indications could be identified at both the applicable inspections.

Due to the uncertainties in the eddy current process, some of the growth comparisons are expected to result in decreases in voltage (i.e., negative growth). Per Generic Letter 95-05, it is appropriate to consider these negative growth rates as part of the average growth rate. The use of the negative growth rates applies only when determining the upper voltage repair limit, otherwise the negative growth values are combined in the zero volt growth voltage bin.

For the projected Cycle 10, the active and deplugged indications are combined using the formulation reviewed in Section 4.6. Since more than 200 active tube indications are analyzed, a DCPP Unit 2 specific growth curve is used, instead of the conservative industry-bounding growth curve.

Table 3-7 provides average Cycle 9 growth rates per steam generator for the 453 DOS indications in active tubes. Each of the four SGs showed an overall positive average-cycle growth rates ranging from about 0.052 to 0.253 volts per cycle. The composite average growth for DCPP Unit 2 during Cycle 9 was 0.196 volts, which is equivalent to 0.134 volts per EFPY. This rate is just over twice the rate of 0.051 volts per EFPY found during 2R8. The 2R9 composite average EOC-9 voltage was 0.377, resulting in an average Cycle 9 growth rate of 35.6% per EFPY.

Table 3-7 also provides the average growth rates per SG for indications found in deplugged tubes. The growth rate for deplugged tubes was found to be about 20.2% per EFPY while out of service. These overall and generator-specific growth rates are for information only since these tubes were out of service during both Cycle 8 and 9, and one tube was also out of service during Cycle 7.

As indicated, the growth component for the active tube indications can now be utilized based on actual DCPP 2R9 data rather than using the bounding industry growth rates. However, the growth component for the deplugged tube indications must be based on an EPRI bounding industry growth rate curve. The two component growths are combined to determine the projected Cycle 10 growth rate to be included in the Monte Carlo simulation. Further explanation of determining the growth distributions is reviewed in Section 4.6.

Recently, some plants with ¾" tube SGs experienced growth rates that seem to increase with the beginning of cycle (BOC) voltage. None of the previous DCPP ARC outages have shown this trend. The trend is generated by plotting Cycle 9 growth rate against BOC-9 voltages. The resulting plot is shown in Figure 3-2. It is apparent from this figure that there is a potential trend of increasing growth with respect to increasing BOC voltages. The data suggests that there may be some voltage dependence on growth. Proposed revisions to leak and burst projection methodology to account for voltage dependent growth are presented in Ref. 18, and NEI letter dated September 22, 1999 (Ref. 20) requested NRC approval of the proposed methodology. Per Ref. 18, this trend had not been previously identified in plants with a less than 3 volt repair criteria.

Per Figure 3-2, the increase in growth appears to begin at about 0.75 BOC voltage threshold as suggested in Ref. 18. This increase, however, is not considered to be at a level of significance to warrant a revision to the leak and burst projection methodology. As recommended in Ref. 18, potential BOC voltage dependent growth trends will continue to be monitored at both DCPP Units.

Table 3-6 provides a summary of the largest voltage growth intersections identified during 2R9, for information only.

3.7 Upper Voltage Repair Limit

Per Generic Letter 95-05, the upper repair limit must be calculated prior to each outage, and the more conservative of the plant-specific average growth rate per EFPY or 30 percent per EFPY should be used as the anticipated growth rate input for this calculation. The upper voltage repair limit was calculated prior to the 2R9 inspection and was determined to be 5.1 volts (Ref. 9). This calculation used a 30 percent per EFPY growth based on the following formula:

$$V_{URL} = \frac{V_{SL}}{1 + \frac{\%V_{NDE}}{100} + \frac{\%V_{CG}}{100}}$$

where: V_{URL} = upper voltage repair limit,
V_{NDE} = NDE voltage measurement uncertainty = 20%,
V_{CG} = voltage growth anticipated between inspections = 30%,
V_{SL} = voltage structural limit from the burst pressure – Bobbin voltage correlation, where the limit of 8.3 volts was used based on Ref. 7.

Although the upper repair limit will not be calculated again until shortly before the next inspection, the average growth rates from Cycle 9 are documented in this report to verify the limiting growth rate to be used for the 2R10 outage. As indicated, the 30% per EFPY NRC minimum limit is no longer bounding for DCPP Unit 2. Table 3-7 shows that the average percent growth for active tubes for Cycle 9 is 35.6% per EFPY. Therefore, the upper voltage repair limit for the 2R10 inspections will be about 4.8 volts, due primarily to the higher growth rate.

3.8 Bobbin Coil Probe Wear

3.8.1 Implementation of the Wear Criteria

The probe wear criteria approved by the NRC (Ref. 12) was applied during the EOC-9 inspection. This reference provides the guidelines to be used for Bobbin probe wear associated with voltage-based repair implementation. When a probe does not pass the 15% wear limit, this criteria requires that tubes with indications above 75% of the repair limit and inspected since the last successful probe wear check be re-inspected with a good probe. Since the repair limit for DCPP-2 is 2.0 volts, all tubes containing indications above 1.5 volts that were originally inspected with a worn probe were required to be re-inspected with a new probe. A summary of probe wear monitoring at DCPP-2 during 2R9 was reviewed in Ref. 10.

During the 2R9 inspections, 3 DOS indications in excess of 1.5 volts were inspected with a probe that failed the wear check. These "RSS" indications were each located in SG 2-4. The 3 tubes that contained these indications were re-inspected per the requirements but there were 2 more that were not re-inspected as reviewed in Section 3.8.2. The re-inspected voltage values are typically very near the original voltages (within 5%). These voltage results provide confirmation that indications less than 1.5 volts that were inspected with worn probes do not need to be re-inspected and that the 75% criterion is adequate.

The Ref. 12 probe wear criteria also require an assessment of tubes that were inspected with probes that failed the wear check in 2R8 but were not re-inspected because they either contained no indication, or the indication was below the 1.5 volt threshold for re-inspection. Specifically, an evaluation is required if "large" indications and/or a non-proportionate number of new indications are detected in tubes which were inspected with a probe that failed the probe check in the prior outage. This evaluation should also address whether or not a more restrictive probe wear criteria is needed. Per Ref. 12, "Large" is defined to be greater than approximately 0.5 volts. This evaluation is now required for DCPP-2 since 2R9 is the second implementation of the ARC.

The results of this evaluation are summarized in Table 3-8. As indicated, 301 of the 485 DOS indications found during 2R9 were new, and 80 of the 301 new indications (27%) were inspected with a worn probe in 2R8. 109 of the new indications were > 0.5 volts and of those 24 (22%) were inspected with a worn probe in 2R8. Overall, about 32% of the total tube population was inspected with worn probes in 2R8. Therefore, the number of new indications detected in tubes that were inspected by worn probes in 2R8 is proportionate to the number of tubes inspected with worn probes. As such, probe wear is not considered to be a reason for the large number of new DOS indications detected during 2R9.

There were 24 new "large" indications that were inspected with a worn probe in the prior outage. Only two were greater 1.0 volt and both were located in SG 2-3 at 1H. The largest new DOS indication was a 2.21 volt indication and the other was 1.94 volts. Each of these flaws however was evident during the look-ups for growth. It should be noted that the 2.21 volt and the 1.94 volt indications were found to be 0.82 volts and 0.69 volts, respectively, from the 2R8 inspection data. Therefore, probe wear is not considered to be the reason for these DOS indications not being called in 2R8. POD is the likely reason these indications were "new" in 2R9 since DCPP Unit 2 POPCD is less than 0.6 for indications less than approximately 0.8 volts (see Table 6-2).

As required by Refs. 9 and 12, since this is the second implementation of the voltage-based criteria at Unit 2, a comparison must be performed of the actual versus the projected EOC-9 voltage distribution from the 2R8 analysis (Ref. 14). In addition, if any significant differences exist (e.g., number of indications, size of largest indication, distribution of indications, etc.), the root cause must be evaluated and reported to the NRC.

The comparisons are shown on Figures 3-3 through 3-6. In all SGs, projected EOC-9 distribution under predicts the actual EOC-9 distribution for small indications (less than approximately 0.7 volts). This is expected because the DCPP Unit 2 POPCD is less than 0.6 for indications less than approximately 0.8 volts.

As indicated, the voltage distributions for SG 2-1 are well bounded by the projected EOC-9 voltages. However, for SGs 2-2, 2-3, and 2-4, there are a few instances where the projected EOC-9 distribution under predicts the actual EOC-9 distribution at the tails of the distribution. There are several potential contributing factors for this under prediction. First, three new large indications (greater than 1.8 volts) were detected in 2R9 that experienced high growth rates based on lookup analyses, and a small number of repeat indications from 2R8 greater than 1.8 volts also experienced high growth rates (1.3 volts on the average). Secondly, relatively few indications were found in 2R8 and most were small.

Another contributing factor to the under prediction of the larger indications is the fact that the largest growths occurred in indications which were greater than about 0.7 volts at the beginning of the cycle. The Monte Carlo analysis randomly assigns growth values to the beginning of cycle voltages. Therefore, for the Monte Carlo analysis, the majority of the large growths are going to be in indications near the average voltage, i.e., where the majority of the indications occur (<0.7 volts). This trend of higher growth rates dependent on higher BOC voltages will continue to be monitored as identified previously in Section 3.6.

The NRC requirements regarding probe wear monitoring were complied with during the 2R9 eddy current examination at DCPP Unit 2, with the exceptions noted in the following Section 3.8.2. It is concluded that the current 75% probe wear criteria is adequate and that a more restrictive probe wear criteria is not needed.

3.8.2 Missed Bobbin Retest Indications

Two intersections with DOS indications greater than 1.5 volts that were originally inspected with a worn bobbin probe were inadvertently not re-inspected by a new bobbin probe, in violation of

PG&E procedures and NRC commitments. This nonconformance was discovered by FTI after the outage.

During 2R9, measurements of probe wear were performed by certified acquisition personnel using the ZETEC Eddynet Probe Wear Widget. The initial voltage measurements (from the ASME wear standard) taken when the probe is "new" are compared individually to measurements taken at each final calibration interval. The "widget" automatically calculates the maximum percent out of tolerance as compared to the initial average voltage readings. Tolerances for any hole greater than +/- 15% designate the probe as "ARC OUT". If the maximum final calibration is good (less than +/- 15%), the Cal group is "ARC IN", and the operator can proceed to open the next Cal group and continue acquiring data. However, before proceeding to the next Cal, the current Cal status must be recorded on the Cal board by the operator. Upon their review, the resolution analysts were required to check the Cal board and to edit the DOS call to a retest code (RSS) if the Cal is ARC OUT and the voltage is above 1.5 volts.

An FTI NCR (noncomformance report) was generated (Ref. 16) to address a resolution for this discrepancy. The disposition is summarized in Section 3.8.3. The tube locations were R4C46 at 2H and R36C48 at 2H, both in SG 2-4. The Bobbin and Plus Point results for these intersections are shown in Table 3-9. Note that R4C46 at 2H was inspected by Plus Point because the intersection was originally called DIS. Plus Point did not confirm any crack-like degradation. The second missed retest intersection however was only inspected once with Bobbin.

3.8.3 Disposition of Missed Retest Inspections

It was concluded that acceptance of the "ARC Out" Bobbin inspection results do not present a safety, structural or operability concern to DCPP Unit 2. The Bobbin voltages of these locations are not approaching the LRL of 2.0 volts, which would require repair if the indications confirmed as crack-like by Plus Point.

Previous experience at DCPP and other similar plants has demonstrated that there is minimal difference between the voltage from a "good" probe versus that from a "worn" probe. Table 3-10 shows the Bobbin results as well as the average probe wear percent voltage deviation calculated by the probe wear "widget" for the 3 RSS calls that were correctly re-tested during 2R9 along with the same data from the missed retest indications. The differences in DOS and RSS voltages were no more than 2 percent. The maximum "out of tolerance" percent voltage of the four holes during the final cal check determines the cal status. This tolerance indicates the centering capability of the probe feet and can be either negative or positive as shown in Table 3-10 (last column to right), depending on which side of the feet is most worn. These tolerances confirm that the amount of deviation or "out of tolerance" calculated during the final check for the missed indications is about the same as those that were correctly re-tested.

As a conservative measure, the voltages of these two indications were increased by 15% to 1.96 volts and 1.89 volts, respectively, for input into the BOC-10 voltage distribution and growth calculations. These increased voltages remain below the 2.0 volt LRL.

Several corrective actions are addressed in the NCR to prevent reoccurrence of missed retest indications for probe wear during future inspections.

3.8.4 Use of Bobbin Probes with Changeable Feet Centering

The centering feet on a Bobbin probe are the parts that wear most during use, and this wear is the bases for implementing the ±15% wear tolerance criteria to ensure consistent quality of the Bobbin voltage signals. The Ref. 11 safety evaluation determined that the use of the changeable feet Bobbin probe meets the NRC requirements when implementing the voltage-based repair criteria. Changeable feet Bobbin probes were used for data acquisition during the 1R9 and 2R9 outages with the following restrictions.

When the probe failed the probe wear check, this new design allows the centering feet to be replaced in lieu of replacing the entire probe. Replacing the feet and subsequently acquiring an acceptable new wear calibration permitted the probe to be treated as "new" again. In addition to wear measurements, Ref. 11 required a check of the signal-to-noise (S/N) ratio using the 40% TW ASME standard hole at each subsequent feet replacement. If the S/N ratio is determined to change by more than 30% with respect to the original S/N ratio for that probe with the original centering feet, it is considered to be indicative of a potential probe electrical deficiency. At this point, the entire probe assembly should be replaced. Probes with feet changeout results in the optimum number of probe heads being used and less radiation exposure for platform personnel since the feet changeout takes less time than a probe change out.

3.9 AONDB Bobbin Correlation

Section 8.1.3 of Ref. 7 addresses a methodology for assigning a Bobbin voltage for indications detected only by RPC inspection. These indications, referred to as AONDB at DCPP, are typically found as a result of dented TSP exams or other types of special interest inspection programs. Prior to Ref. 7, AONDB indications were plugged at DCPP (i.e., 2R8 and 1R9, Refs. 14 and 17) but they were used in the ARC Monte Carlo analyses. In 2R8 and 1R9, assigned Bobbin voltages were calculated using a simple linear regression correlation developed from the current outage Bobbin and Plus Point data without any statistical enhancements.

In 2R9, the Ref. 7 methodology was implemented. A historical DCPP (both Units) correlation was developed to assign Bobbin voltages to AONDB indications at DCPP (Ref. 19). For application to dents less than or equal to 5 volts and mix residuals, the following Ref. 7 recommendations were implemented: Bobbin voltages are inferred from the Bobbin to Plus Point correlation at 95% confidence on the mean correlation; Bobbin voltages inferred from Plus Point voltages by application of the correlation are included in the condition monitoring and operational assessments for burst probability and MSLB leak rate calculations; Bobbin voltages greater than the 2 volt LRL are repaired; and Bobbin voltages greater than or equal to 1.0 volt found in a Bobbin coil mix residual signal are repaired.

During the 2R9 inspection, AONDB indications were found in 10 tube intersections. 9 intersections were dented and 1 intersection contained a support plate residual. In all cases, the bobbin DOS signal was masked by the dent or residual. The eddy current results are shown in Table 3-11. Bobbin voltages were assigned using the Figure 3-1 correlation. The assigned voltages were less than the 2 volt LRL for the dented intersections, and less than 1 volt for the mix residual intersection. Therefore, all intersections were allowed to remain in service, except for SG 2-2 R14C89 at 1H which was required to be plugged because the associated dent voltage was 14.01 volts (exceeding the 5 volt dent criteria).

Figure 3-1 shows the DCPP historical data with the 1st order fit mean and the recommended Upper 95% confidence projections. The result indicates that a 2.0 volt Bobbin call would result from a 1.75 volt Plus Point ODSCC call (using the Upper 95% fit). Also from the 95% line, the Plus Point voltage equivalent to a 1.0 volt Bobbin voltage is 0.71 volts. The r^2 value and the P-value for slope were 42.81% and 1.76e-50, respectively, for the mean fit. Utilizing the 95% line is recommended in Ref. 7 to apply a level of conservatism to the correlation.

The plant-specific correlation to compute assigned Bobbin voltages for AONDB indications based on an Upper 95% CL was found to be:

$$V_B = V_{+Pt} * (0.96183) + 0.31202 \text{ volts.}$$

Table 3-1
2R9 DOS Indications ≥ 2.0 Volts in Active Tubes

SG	Row	Col	Ind	Elev	Inch1	Volts	Deg	Probe
22	13	86	DOS	2H	0.14	2.89	69	720MU
	13	86	SAI	2H	0.03	1.99	70	720+P
23	8	78	DOS	1H	0.24	2.21	77	720MU
	8	78	SAI	1H	-0.02	0.17	107	720+P
	8	78	SAI	1H	0.07	2.28	74	720+P
24	16	50	DOS	1H	-0.02	2.11	80	720MU
	16	50	SAI	1H	-0.09	0.79	63	720+P
	16	50	SAI	1H	0	0.64	85	720+P
	5	54	DOS	1H	-0.05	2.15	70	720MU
	5	54	SAI	1H	-0.07	1.56	54	720+P
	5	54	SAI	1H	-0.01	0.1	67	720+P
	8	75	DOS	1H	0.12	2.54	54	720MU
	8	75	SAI	1H	0.04	1.21	60	720+P
	17	84	DOS	2H	0	2.34	62	720MU
	17	84	SAI	2H	-0.08	2.22	57	720+P

Table 3-2
2R9 DOS Indications ≥ 2.0 Volts in Deplugged Tubes

SG	Row	Col	Ind	Elev	Inch1	Volts	Deg	Probe
21	24	46	DOS	1H	0.1	3.02	88	720MU
			SAI	1H	0.05	0.74	95	720+P
			SAI	1H	0.06	0.22	111	720+P
	27	45	DOS	1H	0.07	2.98	99	720MU
			SAI	1H	-0.01	1.41	96	720+P

Table 3-3
DCPP-2 October 1999 Outage (2R9)
Summary of the Largest Voltages for EOC-9

SUMMARY OF LARGEST VOLTAGES FOR VOLTAGE-BASED ARC REVIEW										
SG	Count	Row	Col	Elev	1999 Bobbin Voltages			RPC Confirmed?	Deplugged 2R9?	Repaired Tube
					EOC	BOC	GROWTH			
21	1	24	46	1H	3.02	0.99	2.03	Yes	Yes	Yes
21	2	27	45	1H	2.98	0.5	2.48	Yes	Yes	Yes
22	3	13	86	2H	2.89	1.33	1.56	Yes		Yes
24	4	8	75	1H	2.54	0.76	1.78	Yes		Yes
24	5	17	84	2H	2.34	0.71	1.63	Yes		Yes
23	6	8	78	1H	2.21	0.82	1.39	Yes		Yes
24	7	5	54	1H	2.15	0.78	1.37	Yes		Yes
24	8	16	50	1H	2.11	1.36	0.75	Yes		Yes
24	9	4	46	2H	1.96	0.91	1.05			
23	10	27	59	1H	1.94	0.69	1.25			
24	11	38	60	2H	1.93	0.9	1.03			
24	12	5	48	1H	1.89	0.9	0.99			
24	13	36	48	2H	1.89	0.84	1.05			
24	14	13	63	1H	1.76	0.8	0.96			
24	15	24	73	2H	1.62	0.23	1.39	Yes	Yes	
24	16	8	63	1H	1.58	0.66	0.92			
23	17	24	26	2H	1.48	0.6	0.88			
24	18	31	45	1H	1.47	0	1.47	Yes	Yes	
24	19	7	80	3H	1.47	0	1.47	Yes	Yes	
24	20	42	48	2H	1.39	0.45	0.94			
24	21	8	6	1H	1.35	0.79	0.56	Yes	Yes	
24	22	4	45	1H	1.35	0.64	0.71			
24	23	38	47	2H	1.34	0.52	0.82			
24	24	24	84	1H	1.31	0.77	0.54			
24	25	28	29	2H	1.3	0.96	0.34			
24	26	15	77	2H	1.3	0.39	0.91	Yes	Yes	
24	27	29	35	1H	1.28	0.61	0.67			
24	28	23	42	2H	1.28	1.05	0.23	Yes	Yes	
23	29	6	54	1H	1.27	0.65	0.62			
24	30	15	38	1H	1.26	0.51	0.75			
24	31	3	51	1H	1.26	0.61	0.65			
24	32	24	38	1H	1.25	0.91	0.34			
24	33	16	57	2H	1.25	0.8	0.45			
21	34	13	36	1H	1.23	0.3	0.93	Yes	Yes	
24	35	30	20	2H	1.22	0.87	0.35	Yes	Yes	
24	36	19	84	2H	1.22	0.52	0.7			
24	37	7	84	2H	1.21	0.37	0.84			
24	38	22	48	2H	1.2	0.53	0.67	Yes	Yes	
24	39	5	50	1H	1.2	0.44	0.76			
23	40	17	57	1H	1.19	0.6	0.59	Yes	Yes	
24	41	33	32	2H	1.19	0.5	0.69	Yes	Yes	
24	42	11	47	2H	1.18	0.84	0.34			
24	43	14	88	2H	1.18	0.9	0.28	Yes	Yes	
24	44	38	65	2H	1.13	0.82	0.31	Yes	Yes	
24	45	21	26	2H	1.12	1	0.12			
24	46	3	69	1H	1.11	0.76	0.35	Yes	Yes	
24	47	10	76	2H	1.11	0.51	0.6			
24	48	7	62	1H	1.1	0.43	0.67			
22	49	38	40	1H	1.08	0.49	0.59			
24	50	19	41	2H	1.08	0.7	0.38	Yes	Yes	
24	51	26	59	2H	1.08	0.21	0.87			
24	52	18	80	2H	1.07	0.44	0.63			
21	53	17	33	1H	1.06	0.73	0.33	Yes	Yes	
22	54	3	13	2H	1.05	1.2	-0.15			
24	55	13	66	2H	1.05	0.62	0.43	Yes	Yes	
24	56	27	69	2H	1.04	0.62	0.42			
22	57	22	67	2H	1.01	0.46	0.55			
24	58	4	68	2H	1.01	0.67	0.34	Yes	Yes	
24	59	25	60	2H	1	0.7	0.3			
24	60	23	76	2H	1	0.54	0.46			

Table 3-4
DCPP-2 October 1999 Outage (2R9)
Average and Maximum Voltages By Elevation for Active Tubes in Service during Cycle 9

Tube Support Plate	Steam Generator 2-1 Number of Indications	Steam Generator 2-1 Maximum Voltage	Steam Generator 2-1 Average Voltage	Tube Support Plate	Steam Generator 2-2 Number of Indications	Steam Generator 2-2 Maximum Voltage	Steam Generator 2-2 Average Voltage
1H	62	0.99	0.461	1H	23	1.08	0.426
2H	15	0.88	0.384	2H	24	2.89	0.600
3H	6	0.73	0.375	3H	5	0.49	0.358
4H	3	0.45	0.330	4H	2	0.65	0.505
5H	10	0.62	0.443	5H	2	0.23	0.185
6H	1	0.32	0.320	6H	1	0.23	0.230
7H	0	0.00	0.000	7H	0	0.00	0.000
CL	2	0.69	0.550	CL	1	0.39	0.390
All Inds	99	0.99	0.44	All Inds	58	2.89	0.48

Tube Support Plate	Steam Generator 2-3 Number of Indications	Steam Generator 2-3 Maximum Voltage	Steam Generator 2-3 Average Voltage	Tube Support Plate	Steam Generator 2-4 Number of Indications	Steam Generator 2-4 Maximum Voltage	Steam Generator 2-4 Average Voltage
1H	33	2.21	0.596	1H	93	2.54	0.673
2H	10	1.48	0.488	2H	139	2.34	0.621
3H	4	0.84	0.590	3H	36	0.89	0.543
4H	0	0.00	0.000	4H	5	0.97	0.574
5H	3	0.69	0.527	5H	0	0.00	0.000
6H	2	0.92	0.565	6H	0	0.00	0.000
7H	0	0.00	0.000	7H	0	0.00	0.000
CL	0	0.00	0.000	CL	3	0.35	0.277
All Inds	52	2.21	0.57	All Inds	276	2.54	0.62

Tube Support Plate	Composite of All Four SGs Number of Indications	Composite of All Four SGs Maximum Voltage	Composite of All Four SGs Average Voltage
1H	211	2.54	0.572
2H	188	2.89	0.592
3H	51	0.89	0.509
4H	10	0.97	0.487
5H	15	0.69	0.425
6H	4	0.92	0.420
7H	0	0.00	0.000
CL	6	0.69	0.387
All Inds	485	2.89	0.56

Note: CL indicates a cold-leg indication at any elevation.

Table 3-5
DCPP-2 October 1999 Outage (2R9)
Average and Maximum Voltages By Elevation for Deplugged Tubes Not in Service during Cycle 9

Tube Support Plate	Steam Generator 2-1			Tube Support Plate	Steam Generator 2-2		
	Number of Indications	Maximum Voltage	Average Voltage		Number of Indications	Maximum Voltage	Average Voltage
1H	9	3.02	1.182	1H	2	0.89	0.665
2H	1	0.35	0.350	2H	4	0.66	0.390
3H	1	0.75	0.750	3H	1	0.10	0.100
4H	0	0.00	0.000	4H	0	0.00	0.000
5H	0	0.00	0.000	5H	0	0.00	0.000
6H	0	0.00	0.000	6H	0	0.00	0.000
7H	0	0.00	0.000	7H	0	0.00	0.000
CL	0	0.00	0.000	CL	0	0.00	0.000
All Inds	11	3.02	1.07	All Inds	7	0.89	0.43

Tube Support Plate	Steam Generator 2-3			Tube Support Plate	Steam Generator 2-4		
	Number of Indications	Maximum Voltage	Average Voltage		Number of Indications	Maximum Voltage	Average Voltage
1H	5	1.19	0.694	1H	17	1.47	0.695
2H	1	0.57	0.570	2H	31	1.62	0.780
3H	0	0.00	0.000	3H	3	1.47	0.927
4H	0	0.00	0.000	4H	2	0.40	0.355
5H	0	0.00	0.000	5H	1	0.53	0.530
6H	0	0.00	0.000	6H	0	0.00	0.000
7H	0	0.00	0.000	7H	0	0.00	0.000
CL	0	0.00	0.000	CL	0	0.00	0.000
All Inds	6	1.19	0.67	All Inds	54	1.62	0.74

Tube Support Plate	Composite of All Four SGs		
	Number of Indications	Maximum Voltage	Average Voltage
1H	33	3.02	0.826
2H	37	1.62	0.721
3H	5	1.47	0.726
4H	2	0.40	0.355
5H	1	0.53	0.530
6H	0	0.00	0.000
7H	0	0.00	0.000
CL	0	0.00	0.000
All Inds	78	3.02	0.75

Note: CL indicates a cold-leg indication at any elevation.

Table 3-6
DCPP Unit 2 October 1999 Outage (2R9)
Summary of the Largest Voltage Growths for Cycle 9 (1998-1999)

SUMMARY OF LARGEST VOLTAGE GROWTH RATES FOR VOLTAGE-BASED ARC REVIEW										
SG	Count	Row	Col	Elev	1999 Bobbin Voltages			RPC Confirmed?	Deplugged 2R9?	Repaired Tube
					EOC	BOC	GROWTH			
21	1	27	45	1H	2.98	0.5	2.48	Yes	Yes	Yes
21	2	24	48	1H	3.02	0.99	2.03	Yes	Yes	Yes
24	3	8	75	1H	2.54	0.76	1.78	Yes		Yes
24	4	17	84	2H	2.34	0.71	1.63	Yes		Yes
22	5	13	86	2H	2.89	1.33	1.56	Yes		Yes
23	6	8	78	1H	2.21	0.82	1.39	Yes		Yes
24	7	24	73	2H	1.62	0.23	1.39	Yes	Yes	
24	8	5	54	1H	2.15	0.78	1.37	Yes		Yes
23	9	27	59	1H	1.94	0.69	1.25			
24	10	4	46	2H	1.96	0.91	1.05			
24	11	36	48	2H	1.89	0.84	1.05			
24	12	38	60	2H	1.93	0.9	1.03			
24	13	5	48	1H	1.89	0.9	0.99			
24	14	13	63	1H	1.76	0.8	0.96			
24	15	42	48	2H	1.39	0.45	0.94			
21	16	13	36	1H	1.23	0.3	0.93	Yes	Yes	
24	17	8	63	1H	1.58	0.66	0.92			
24	18	15	77	2H	1.3	0.39	0.91	Yes	Yes	
23	19	24	26	2H	1.48	0.6	0.88			
24	20	26	59	2H	1.08	0.21	0.87			
24	21	7	84	2H	1.21	0.37	0.84			
24	22	38	47	2H	1.34	0.52	0.82			
24	23	5	50	1H	1.2	0.44	0.76			
24	24	15	38	1H	1.26	0.51	0.75			
24	25	16	50	1H	2.11	1.36	0.75	Yes		Yes
24	26	13	76	2H	0.91	0.19	0.72	Yes		
24	27	4	45	1H	1.35	0.64	0.71			
24	28	19	84	2H	1.22	0.52	0.7			
24	29	33	32	2H	1.19	0.5	0.69	Yes	Yes	
23	30	4	49	1H	0.88	0.19	0.69	Yes		
24	31	7	62	1H	1.1	0.43	0.67			
24	32	29	35	1H	1.28	0.61	0.67			
24	33	22	48	2H	1.2	0.53	0.67	Yes	Yes	
21	34	23	43	1H	0.84	0.17	0.67	Yes	Yes	
24	35	3	51	1H	1.26	0.61	0.65			
24	36	18	80	2H	1.07	0.44	0.63			
23	37	6	54	1H	1.27	0.65	0.62			
24	38	10	76	2H	1.11	0.51	0.6			
22	39	38	40	1H	1.08	0.49	0.59			
24	40	4	40	3H	0.9	0.31	0.59	Yes	Yes	
23	41	17	57	1H	1.19	0.6	0.59	Yes	Yes	
24	42	8	6	1H	1.35	0.79	0.56	Yes	Yes	
24	43	4	40	1H	0.8	0.24	0.56	Yes	Yes	
22	44	22	87	2H	1.01	0.46	0.55			
23	45	32	73	1H	0.7	0.15	0.55	Yes		Yes
24	46	24	84	1H	1.31	0.77	0.54			
24	47	7	81	2H	0.83	0.29	0.54			
24	48	11	77	2H	0.89	0.39	0.5			
21	49	3	54	1H	0.87	0.37	0.5			
21	50	16	89	3H	0.75	0.25	0.5	Yes	Yes	
24	51	35	57	2H	0.87	0.38	0.49			
24	52	3	50	2H	0.85	0.37	0.48			
24	53	8	27	3H	0.89	0.42	0.47			
21	54	24	33	1H	0.88	0.41	0.47			
24	55	24	74	2H	0.8	0.33	0.47			
24	56	23	76	2H	1	0.54	0.46			
24	57	16	57	2H	1.25	0.8	0.45			
23	58	5	5	3H	0.84	0.4	0.44			
24	59	13	66	2H	1.05	0.62	0.43	Yes	Yes	
24	60	28	61	2H	0.89	0.46	0.43			

Table 3-7
DCPP-2 Cycle 9 Voltage Growth Rates

(a) Average Growth for Active Tubes during Cycle 9

Steam Generator	No. of Inds Included In Growth Data	Average BOC-9 Volts	Average Voltage Growth	Average Voltage Growth Per EFPY	Average Percent Growth For Cycle 9 (1)	Average Percent Growth Per EFPY (2)
2-1	93	0.388	0.052	0.036	13.4%	9.2%
2-2	53	0.362	0.128	0.087	35.3%	24.2%
2-3	52	0.324	0.246	0.168	75.9%	52.0%
2-4	255	0.387	0.253	0.173	65.3%	44.7%
Combined	453	0.377	0.196	0.134	52.0%	35.6%

(b) Average Growth for 2R9 Deplugged Tubes while Plugged

Steam Generator	No. of Inds Included In Growth Data	Average Voltage EOC-7	Average Plugged Growth	Average Plugged Growth Per EFPY	Average Percent Growth While Plugged	Average Percent Plugged Growth Per EFPY (3)
2-1	10	0.427	0.721	0.234	168.9%	54.8%
2-2	7	0.357	0.070	0.023	19.6%	6.4%
2-3	6	0.483	0.190	0.062	39.3%	12.8%
2-4 (4)	48	0.483	0.241	0.078	49.9%	16.2%
Combined	71	0.463	0.288	0.093	62.1%	20.2%

Notes:
(1) Average percent growth for Cycle 9 is the average bobbin voltage growth divided by the average BOC-9 voltage.
(2) Average percent growth per EFPY is based on the actual Cycle 9 operating interval of 1.46 EFPY.
(3) Average percent plugged growth per EFPY is based on Cycle 9 plus a Cycle 8 operating interval of 1.62 EFPY.
(4) One indication in SG 2-4 was plugged in 2R6 (Cycle 6 was 1.33 EFPY).

Table 3-8
New 2R9 DOS Indications Reviewed for Probe Wear

SG	New 2R9 Ind. In Tubes Insp. w/ Worn Probe in 2R8	New 2R9 Ind. in Tubes Insp. w/ Good Probe in 2R8	Total New 2R9 DOSs	New 2R9 Ind. > 0.5 Volts	New 2R9 Ind. > 0.5 Volts in Tubes Insp. w/ Worn Probe in 2R8
21	15	33	48	10	2
22	14	20	34	7	3
23	22	18	40	17	9
24	29	150	179	75	10
Tot.	80	221	301	109	24

Table 3-9
2R9 DOSs ≥ 1.5 Volts not Re-tested that Failed the Probe Wear Check

SG	Row	Col	Ind	Elev	Inch	Volts	Ext1	Probe	Cal	ARC Out?
24	4	46	DOS	2H	0	1.70	7H TEH	720MU	SG24H-070	YES
	4	46	DNF	2H	-	-	2H 2H	720+P	SG24H-073	
	36	48	DOS	2H	0.19	1.64	TEHTEC	720MU	SG24C-022	YES
	36	48	Not Tested				2H 2H	720MU	-	

Table 3-10
2R9 Re-tested DOSs Compared to the Missed Retest Indications

SG 2-4	Row	Col	Ind	Elev	Inch	Volts	Cal.	ARC Out?	ARC Tolerance (%)
Re-tested	8	63	RSS	1H	-0.02	1.61	C-030	Yes	-22.23
			DOS	1H	-0.02	1.58	C-041		1.79
	8	75	RSS	1H	0.12	2.50	C-032	Yes	NFC
			DOS	1H	0.12	2.54	C-041		1.79
	13	63	RSS	1H	0	1.73	C-029	Yes	25.78
			DOS	1H	-0.02	1.76	C-041		1.79
Not Re-tested	4	46	DOS	2H	0	1.70	C-070	Yes	18.82
	36	48	DOS	2H	0.19	1.64	C-022	Yes	22.31

Note: NFC indicates no final cal (because the probe died prior to running the wear standard).

Table 3-11
Summary of ODSCC w/o Detectable Bobbin DOS Signals in 2R9

SG	Row	Col	Elev	Plus Point				Dent Voltage	Assigned DOS Voltage
				Ind	Inch	Volts	Deg		
21	6	24	1H	SAI	0.08	0.14	81	1.13	0.45
	3	46	2H	SAI	-0.03	0.16	70	1.76	0.47
	17	55	2H	SAI	-0.09	0.17	100	0.3	0.48
	12	68	2H	SAI	-0.07	0.27	95	0.68	0.57
22	18	30	1H	SAI	-0.19	0.23	138	0.97	0.53
	14	49	1H	SAI	-0.13	0.2	117	14.01	0.50
24	34	43	3H	SAI	0.04	0.31	105	4.49	0.82
			3H	SAI	-0.19	0.22	127		
	10	49	1H	SAI	0.03	0.23	106	1.64	0.53
	16	62	2H	SAI	-0.09	0.07	103	SPR	0.51
			2H	SAI	-0.1	0.14	94		
	18	72	3H	SAI	-0.06	0.11	93	3.46	0.42

Figure 3-1: DCPP Plant-specific Plus Point-to-Bobbin Voltage Correlation.

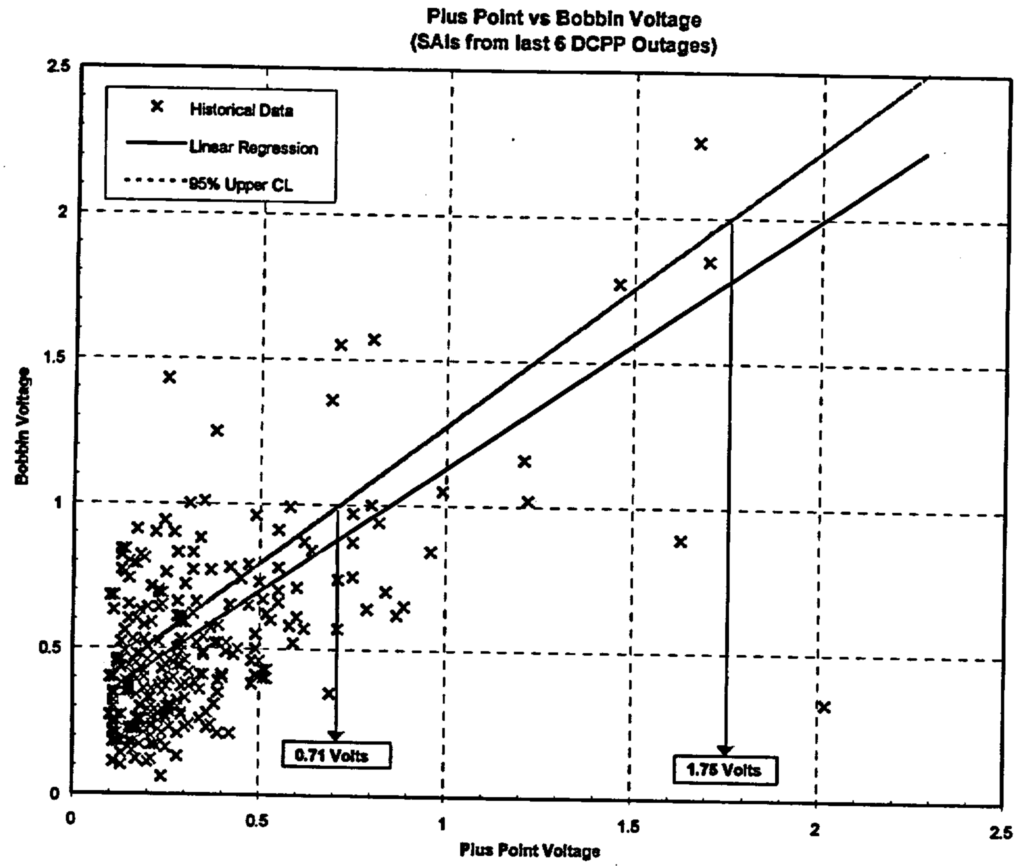


Figure 3-2: Cycle 9 Active Tube Growth Versus BOC-9 Voltage.

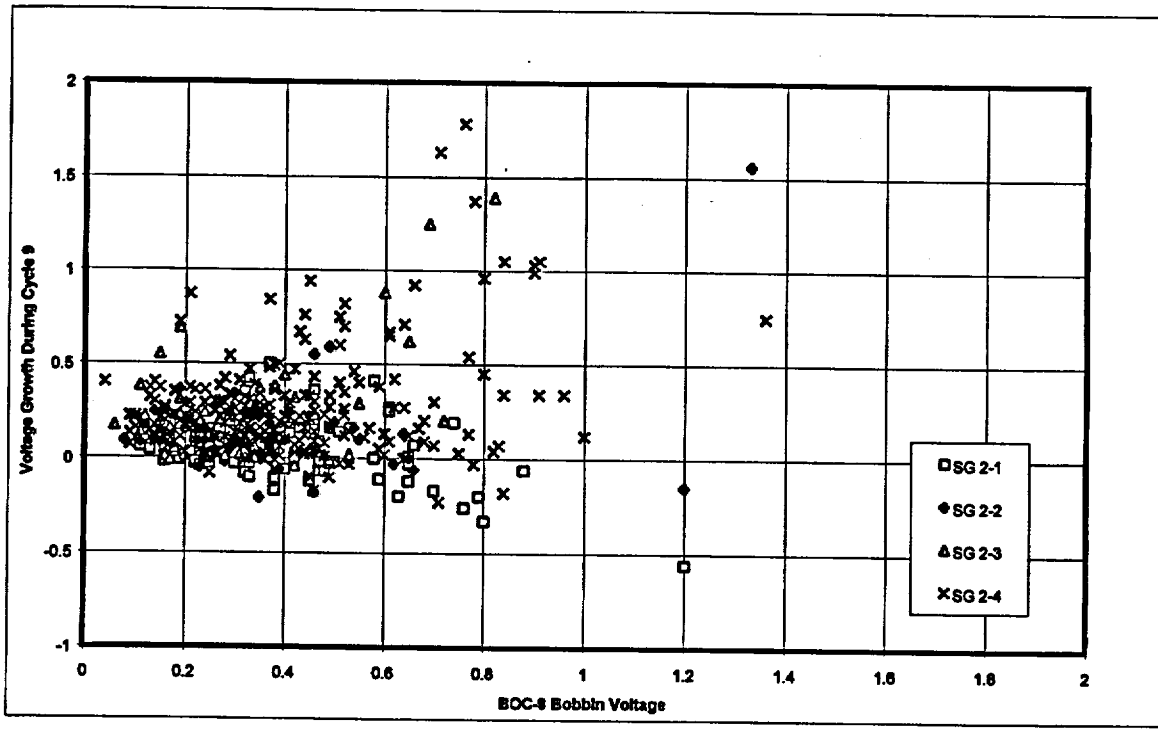


Figure 3-3: SG 2-1 2R9 As-found Compared with 2R8 Projected EOC-9 Voltage Distributions

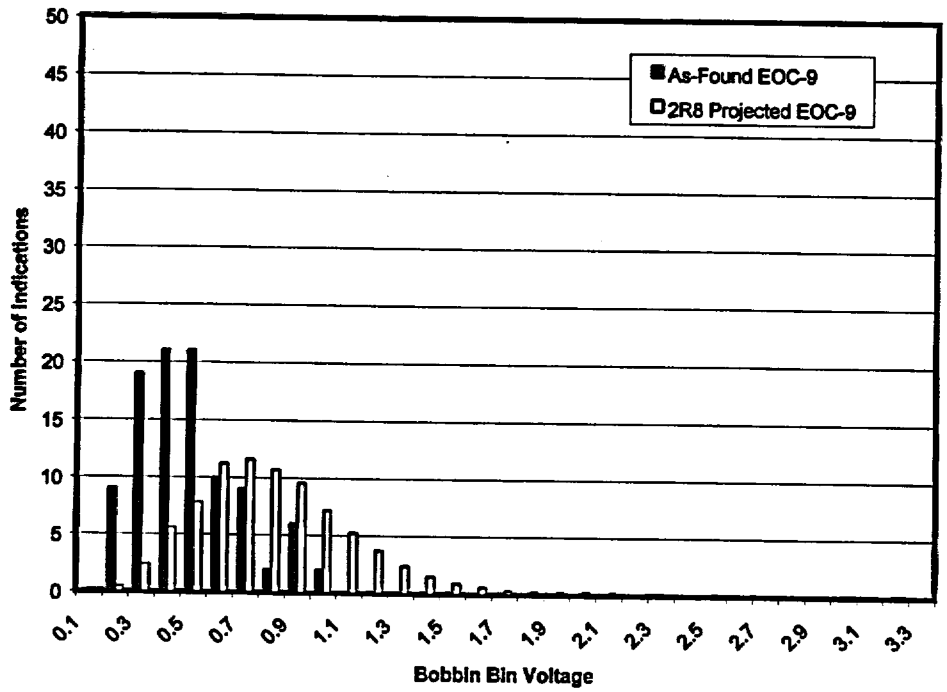


Figure 3-4: SG 2-2 2R9 As-found Compared with 2R8 Projected EOC-9 Voltage Distributions

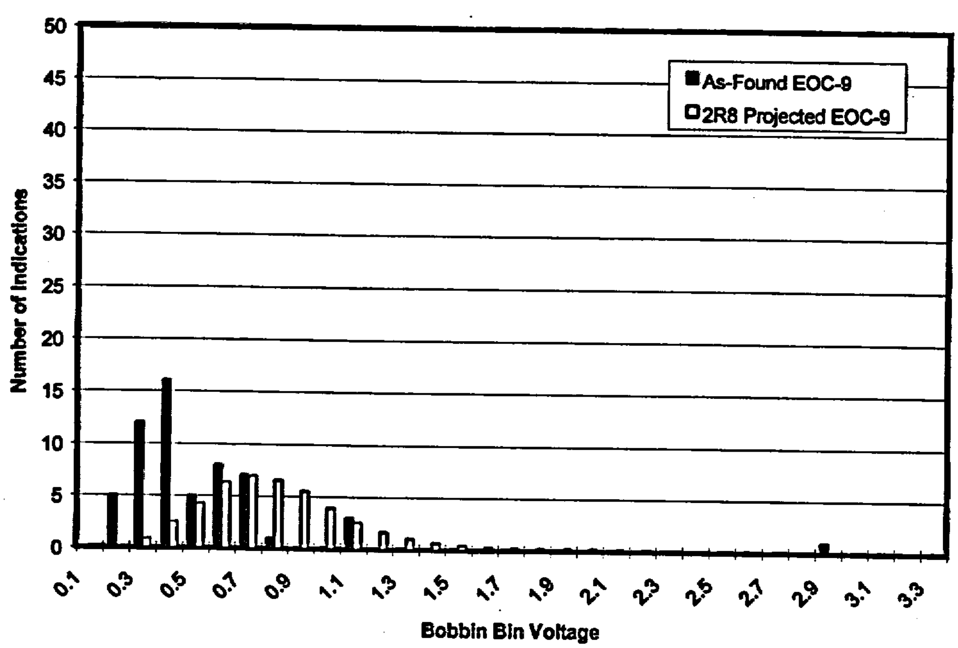


Figure 3-5: SG 2-3 2R9 As-found Compared with 2R8 Projected EOC-9 Voltage Distributions

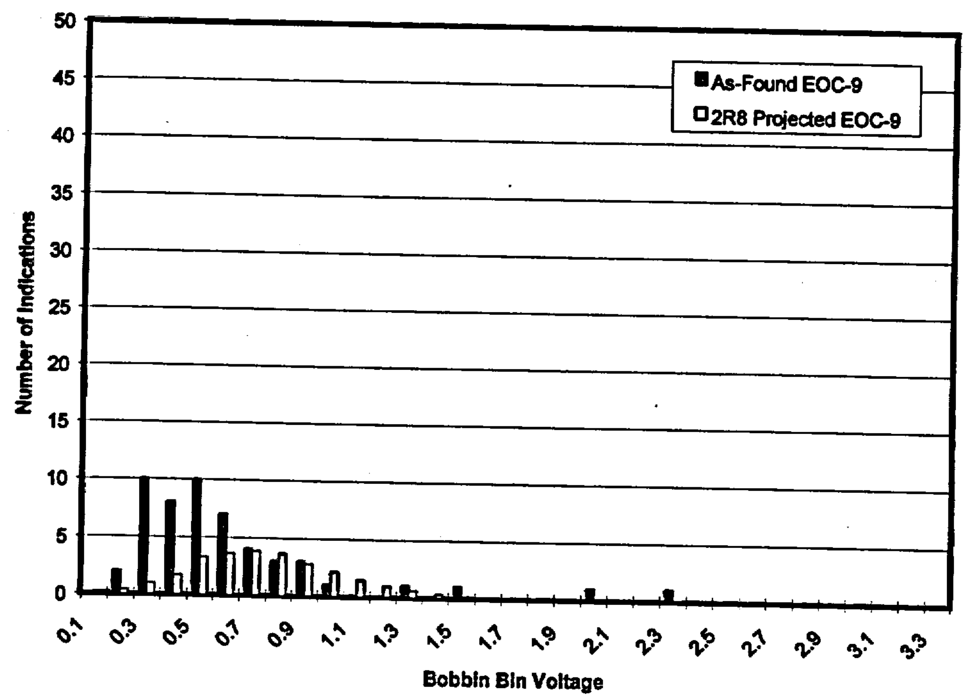
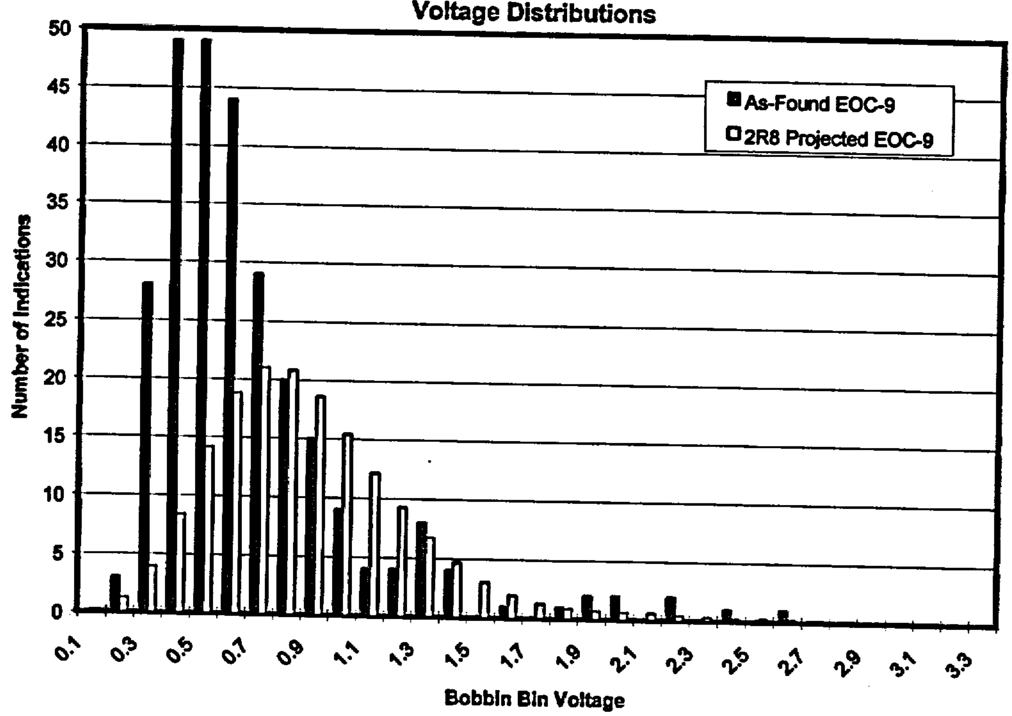


Figure 3-6: SG 2-4 2R9 As-found Compared with 2R8 Projected EOC-9 Voltage Distributions



4.0 Bobbin Voltage Distributions

This section provides the voltage distributions used in the calculation of leak rate and probability of burst as well as calculation of the projected end-of-cycle (EOC-10) distributions.

4.1 EOC-9 (As-Found) Voltage Distributions

The voltages for the DOS indications detected during the 2R9 inspection were binned in 0.1 volt increments separately for the active and deplugged tubes. The "as-found" voltage distributions used in the determination of the EOC-9 and the BOC-10 distributions are shown in Tables 4-1 through 4-4 and in Figures 4-1 through 4-4.

4.2 Repaired Indications

The voltage distributions for the repaired indications are provided in Tables 4-1 through 4-4 and Figures 4-5 and 4-6. A total of 26 DOS indications were removed from service for active tubes (2 in SG 2-1, 5 in SG 2-2, 2 in SG 2-3, and 17 in SG 2-4), and two of the deplugged indications (both in SG 2-1) required repair. A description of the reasons for repair was reviewed in Section 3.5. No indications were repaired because of exceeding the upper repair limit of 5.1 volts.

4.3 DOS Indications Left In Service

As required by the Generic Letter 95-05, the voltage distributions for DOS indications which were returned to service for Cycle 10, regardless of Plus Point confirmation, are shown in Tables 4-1 through 4-4 and Figures 4-9 and 4-10.

The Generic Letter 95-05 also requires that the voltage distribution of the DOS indications which were left in service that were confirmed by Plus Point to be crack-like or were not inspected with Plus Point be provided in the 90-day report. These distributions are provided in Tables 4-1 through 4-4 and Figures 4-7 and 4-8. About 411 DOS indications were not inspected with Plus Point and returned to service, and 102 DOS indications were confirmed by Plus Point as OD-SCC and returned to service. Therefore, this distribution excludes only the DOS indications not confirmed by Plus Point (i.e., DNF calls).

4.4 BOC-10 Voltage Distribution

To determine the BOC-10 voltage distributions, the EOC-9 as-found distributions were adjusted to account for the probability of detection (POD), the indications that were removed from service, and indications from deplugged tubes. In accordance with the requirements of Generic Letter 95-05, a POD of 0.6 was used. The number of indications in each of the EOC-9 voltage bins was therefore divided by the POD of 0.6 to give the total number of indications assumed to be present. This number was then reduced by the number of indications that were removed from service and summed with the number of indications from deplugged tubes. This relationship is shown below:

$$N_{BOC\,10} = \frac{N_{EOC\,9(active)}}{POD} - N_{repaired} + N_{deplugged}\ .$$

The resulting BOC-10 distributions are shown in Tables 4-1 through 4-4 and Figures 4-1 through 4-4.

4.5 Cycle Operating Period

The operating periods used in the growth rate/EFPY calculations and voltage projections are as follows (Ref. 13):

Cycle 9	- BOC-9 to EOC-9 -	1.46 EFPY (actual - 533.62 EFPD)
Cycle 10	- BOC-10 to EOC-10 -	1.44 EFPY (projected - 527 EFPD).

4.6 Voltage Growth Distributions

As previously indicated, the growth distribution for Cycle 10 will have a component from the active tube indications being returned to service and a component from deplugged tube indications being returned to service. The distributions for these are not the same and therefore must be analyzed separately and then combined to obtain the overall growth distribution to be used in the Monte Carlo analysis. An analysis was first performed to determine the growth rate of the DOS indications for in-service tubes. In accordance with the requirements of Generic Letter 95-05, voltage growth rates were only evaluated for those intersections at which Bobbin indications could be identified at both the 2R8 and 2R9 inspections. The actual growth values were divided by the Cycle 9 operating interval of 1.46 EFPY to obtain growth values in terms of delta volts per EFPY. These normalized growth values were then binned in 0.1 volt increments. The DCPP-2 growth distributions for active tubes in Cycle 9 are shown in Table 4-5 and Figures 4-11 and 4-12. For the tube integrity calculations discussed in Section 7, the negative growth values were included as zero growth rates as required by Generic Letter 95-05.

Since DCPP-2 has over the required minimum of 200 indications in its Cycle 9 active tube growth rate distribution, plant-specific growth rate can be used in lieu of the conservative industry bounding growth rate distribution. The cumulative probability distribution function (CPDF) for the three DCPP cycles in which voltage-based ARC was implemented are shown in Figure 4-13. This figure also shows the industry bounding growth distribution.

The growth rate component for the deplugged tubes is based on the conservative limiting EPRI growth distribution since this is the first cycle of operation for the indications deplugged. Ref. 18

provides the methodology to combine the active and deplugged tube growths to project the overall growth for Cycle 10. The formula, taken from Ref. 18 (Equation 8-1), is shown below:

$$n_{i,comb} = (n_{i,ag} \times N_a) \div n_{t,ag} + (n_{i,dg} \times N_{dp}) \div n_{t,dg}$$

where,

$n_{i,comb}$ ≡ number of indications in the i^th bin of Combined growth distribution,
$n_{i,ag}$ ≡ number of indications in the i^th bin of active tube growth distribution,
$n_{i,dg}$ ≡ number of indications in the i^th bin of deplugged tube growth distribution,
N_a ≡ total number of indications in active tubes returned to service,
N_{dp} ≡ total number of indications in deplugged tubes returned to service,
$n_{t,ag}$ ≡ total number of indications in the active tube growth distribution,
$n_{t,dg}$ ≡ total number of indications in the deplugged tube growth distribution.

This correlation normalizes the active and deplugged tube growth distributions to the number of corresponding indications being returned to service. For the SG combined average or composite growth rate, the numbers were normalized to the total number of active and deplugged indications being returned to service. For the generator-specific distributions, the values were normalized to the number returned to service for that generator.

For this analysis, the active tube growth component was based on the 2R9 composite or generator-specific distributions, and the deplugged tube growth component was based on the Ref. 7 limiting growth distribution normalized to the number of deplugged tubes for DCPP-2 (composite or generator-specific).

Tables 4-10 through 4-14 summarize the composite and generator-specific SG combined growth rate distributions. In these tables, the Table 4-9 (deplugged growth) voltage bin setup at the next to last voltage bin (i.e., at 3.9 volts) was inadvertently moved from the 3.8 voltage data bin into the 3.9 voltage bin. This adjustment is conservative and therefore was not corrected for this analysis.

Figure 4-14 shows a comparison of the limiting growth rates for 2R9, i.e., the SG 2-4 growth and the SG composite growth, which were used in the Monte Carlo analyses. The EPRI limiting deplugged growth and the industry-bounding growth rates are shown in the cumulative distribution for comparison.

4.7 NDE Uncertainty Distributions

NDE uncertainties must be taken into account when projecting the end-of-cycle voltages for the next operating cycle. The NDE uncertainties used in the calculations of the EOC-10 voltages are described in Ref. 6. The acquisition uncertainty was sampled from a normal distribution with a mean of zero, a standard deviation of 7%, and a cutoff limit of 15% based on the use of the probe wear standard. The analyst uncertainty was sampled from a normal distribution with a mean of zero, a standard deviation of 10.3%, and no cutoff limit. These uncertainty distributions are shown in Table 4-7 and Figure 4-15.

4.8 Projected EOC-10 Voltage Distributions

The EOC-10 voltage distributions were obtained by applying a Monte Carlo sampling process to the BOC-10 voltages. This process randomly assigns uncertainty values and a growth value to each of the BOC-10 indications. Since the industry bounding growth distribution discussed in Section 4.6 is in terms of delta volts per EFPY, the growth values from this distribution must be corrected for the expected length of Cycle 10. Therefore, the growth values are multiplied by the expected cycle length of 1.44 EFPY. This random sampling process was performed for each BOC-10 indication in the steam generators resulting in a projected EOC-10 voltage for each calculated BOC-10 indication. Each sampling of all of the BOC-10 indications in a steam generator is called a 'trial'. Many trials were performed and the resulting EOC-10 voltages were binned in 0.1 volt increments. The resulting bin values were then divided by the number of trials to obtain the average number of EOC-10 indications per trial in each voltage bin. The projected EOC-10 voltage distributions shown in Table 4-8 and Figures 4-16 through 4-19 are based on 1×10^6 trials.

The EOC-10 projected distributions will be compared to the actual number of indications detected at 2R10 in the next 90 day report per Ref. 12.

Table 4-1: EOC-9 and Calculated BOC-10 Voltage Distributions For SG 2-1.

Voltage Bin	As-found EOC-9	POD (0.6)	Repaired Tubes	Deplugged Tubes	Calculated BOC-10	DOSs Returned to Service: Conf. OD-SCC or Not Insp. w/+Pt	DOSs Returned to Service: Total (1)
0	0	0.00			0.00		
0.1	0	0.00			0.00		
0.2	9	15.00			15.00	9	9
0.3	19	31.67		2	33.67	20	21
0.4	21	35.00		1	36.00	19	22
0.5	21	35.00		1	36.00	20	22
0.6	10	16.67		1	17.67	11	11
0.7	9	15.00			15.00	9	9
0.8	2	3.33		1	4.33	3	3
0.9	6	10.00		1	11.00	7	7
1	2	3.33			3.33	2	2
1.1	0	0.00		1	1.00	1	1
1.2	0	0.00			0.00		
1.3	0	0.00		1	1.00	1	1
1.4	0	0.00			0.00		
1.5	0	0.00			0.00		
1.6	0	0.00			0.00		
1.7	0	0.00			0.00		
1.8	0	0.00			0.00		
1.9	0	0.00			0.00		
2	0	0.00			0.00		
2.1	0	0.00			0.00		
2.2	0	0.00			0.00		
2.3	0	0.00			0.00		
2.4	0	0.00			0.00		
2.5	0	0.00			0.00		
2.6	0	0.00			0.00		
2.7	0	0.00			0.00		
2.8	0	0.00			0.00		
2.9	0	0.00			0.00		
3	0	0.00	1	1	0.00		
3.1	0	0.00	1	1	0.00		
3.2	0	0.00			0.00		
3.3	0	0.00			0.00		
>3.3	0	0.00			0.00		
Total	99	165.00	2	11	174.00	102	108

Note: (1) Total includes all DOSs returned to service, i.e., confirmed, not inspected, and not confirmed with Plus Point.

Table 4-2: EOC-9 and Calculated BOC-10 Voltage Distributions For SG 2-2.

Voltage Bin	As-found EOC-9	POD (0.6)	Repaired Tubes	Deplugged Tubes	Calculated BOC-10	DOSs Returned to Service: Conf. OD-SCC or Not Insp. w/+Pt	DOSs Returned to Service: Total (1)
0	0	0.00			0.00		
0.1	0	0.00		1	1.00	1	1
0.2	5	8.33	1	1	8.33	4	5
0.3	12	20.00			20.00	12	12
0.4	16	26.67		1	27.67	15	17
0.5	5	8.33	1	2	9.33	6	6
0.6	8	13.33	1		12.33	5	7
0.7	7	11.67		1	12.67	7	8
0.8	1	1.67	1		0.67		
0.9	0	0.00		1	1.00	1	1
1	0	0.00			0.00		
1.1	3	5.00			5.00	2	3
1.2	0	0.00			0.00		
1.3	0	0.00			0.00		
1.4	0	0.00			0.00		
1.5	0	0.00			0.00		
1.6	0	0.00			0.00		
1.7	0	0.00			0.00		
1.8	0	0.00			0.00		
1.9	0	0.00			0.00		
2	0	0.00			0.00		
2.1	0	0.00			0.00		
2.2	0	0.00			0.00		
2.3	0	0.00			0.00		
2.4	0	0.00			0.00		
2.5	0	0.00			0.00		
2.6	0	0.00			0.00		
2.7	0	0.00			0.00		
2.8	0	0.00			0.00		
2.9	1	1.67	1		0.67		
3	0	0.00			0.00		
3.1	0	0.00			0.00		
3.2	0	0.00			0.00		
3.3	0	0.00			0.00		
>3.3	0	0.00			0.00		
Total	58	96.67	5	7	98.67	53	60

Note: (1) Total includes all DOSs returned to service, i.e., confirmed, not inspected, and not confirmed with Plus Point.

Table 4-3: EOC-9 and Calculated BOC-10 Voltage Distributions For SG 2-3.

Voltage Bin	As-found EOC-9	POD (0.6)	Repaired Tubes	Deplugged Tubes	Calculated BOC-10	DOSs Returned to Service: Conf. OD-SCC or Not Insp. w/+Pt	DOSs Returned to Service: Total (1)
0	0	0.00			0.00		
0.1	0	0.00			0.00		
0.2	2	3.33			3.33	2	2
0.3	10	16.67			16.67	8	10
0.4	8	13.33		1	14.33	9	9
0.5	10	16.67		1	17.67	11	11
0.6	7	11.67		2	13.67	9	9
0.7	4	6.67	1		5.67	3	3
0.8	3	5.00			5.00	3	3
0.9	3	5.00			5.00	3	3
1	1	1.67		1	2.67	2	2
1.1	0	0.00			0.00		
1.2	0	0.00		1	1.00	1	1
1.3	1	1.67			1.67	1	1
1.4	0	0.00			0.00		
1.5	1	1.67			1.67	1	1
1.6	0	0.00			0.00		
1.7	0	0.00			0.00		
1.8	0	0.00			0.00		
1.9	0	0.00			0.00		
2	1	1.67			1.67	1	1
2.1	0	0.00			0.00		
2.2	0	0.00			0.00		
2.3	1	1.67	1		0.67		
2.4	0	0.00			0.00		
2.5	0	0.00			0.00		
2.6	0	0.00			0.00		
2.7	0	0.00			0.00		
2.8	0	0.00			0.00		
2.9	0	0.00			0.00		
3	0	0.00			0.00		
3.1	0	0.00			0.00		
3.2	0	0.00			0.00		
3.3	0	0.00			0.00		
>3.3	0	0.00			0.00		
Total	52	86.67	2	6	90.67	54	56

Note: (1) Total includes all DOSs returned to service, i.e., confirmed, not inspected, and not confirmed with Plus Point.

Table 4-4: EOC-9 and Calculated BOC-10 Voltage Distributions For SG 2-4.

Voltage Bin	As-found EOC-9	POD (0.6)	Repaired Tubes	Deplugged Tubes	Calculated BOC-10	DOSs Returned to Service: Conf. OD-SCC or Not Insp. w/+Pt	DOSs Returned to Service: Total (1)
0	0	0.00			0.00		
0.1	0	0.00			0.00		
0.2	3	5.00			5.00	3	3
0.3	28	46.67	1	2	47.67	29	29
0.4	49	81.67	6	7	82.67	46	50
0.5	49	81.67	2	11	90.67	57	58
0.6	44	73.33	3	8	78.33	48	49
0.7	29	48.33		3	51.33	31	32
0.8	20	33.33	1	2	34.33	21	21
0.9	15	25.00		4	29.00	18	19
1	9	15.00		2	17.00	11	11
1.1	4	6.67		3	9.67	7	7
1.2	4	6.67		5	11.67	8	9
1.3	8	13.33		3	16.33	11	11
1.4	4	6.67		1	7.67	5	5
1.5	0	0.00		2	2.00	2	2
1.6	1	1.67			1.67	1	1
1.7	0	0.00		1	1.00	1	1
1.8	1	1.67			1.67	1	1
1.9	2	3.33			3.33	2	2
2	2	3.33			3.33	1	2
2.1	0	0.00			0.00		
2.2	2	3.33	2		1.33		
2.3	0	0.00			0.00		
2.4	1	1.67	1		0.67		
2.5	0	0.00			0.00		
2.6	1	1.67	1		0.67		
2.7	0	0.00			0.00		
2.8	0	0.00			0.00		
2.9	0	0.00			0.00		
3	0	0.00			0.00		
3.1	0	0.00			0.00		
3.2	0	0.00			0.00		
3.3	0	0.00			0.00		
>3.3	0	0.00			0.00		
Total	276	460.00	17	54	497.00	303	313

Note: (1) Total includes all DOSs returned to service, i.e., confirmed, not inspected, and not confirmed with Plus Point.

Table 4-5: DCPP-2 October 1999 Outage (2R9) Bobbin Voltage Growth Statistics for Cycle 9 Active Tubes (1998 to 1999) Per EFPY.

Delta Volts	Steam Generator 2-1		Steam Generator 2-2		Steam Generator 2-3	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.4	0	0.000	0	0.000	0	0.000
-0.3	1	0.011	0	0.000	0	0.000
-0.2	1	0.022	0	0.000	0	0.000
-0.1	5	0.075	3	0.057	0	0.000
0.0	31	0.409	9	0.226	4	0.077
0.1	32	0.753	22	0.642	16	0.385
0.2	17	0.935	14	0.906	20	0.769
0.3	4	0.978	2	0.943	5	0.865
0.4	2	1.000	1	0.962	2	0.904
0.5	0	1.000	1	0.981	2	0.942
0.6	0	1.000	0	0.981	0	0.942
0.7	0	1.000	0	0.981	1	0.962
0.8	0	1.000	0	0.981	0	0.962
0.9	0	1.000	0	0.981	1	0.981
1.0	0	1.000	0	0.981	1	1.000
1.1	0	1.000	1	1.000	0	1.000
1.2	0	1.000	0	1.000	0	1.000
1.3	0	1.000	0	1.000	0	1.000
1.4	0	1.000	0	1.000	0	1.000
1.5	0	1.000	0	1.000	0	1.000
Total	93		53		52	

Delta Volts	Steam Generator 2-4		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.4	0	0.000	0	0.000
-0.3	0	0.000	1	0.002
-0.2	0	0.000	1	0.004
-0.1	3	0.012	11	0.029
0.0	13	0.063	57	0.155
0.1	84	0.392	154	0.494
0.2	83	0.718	134	0.790
0.3	39	0.871	50	0.901
0.4	9	0.906	14	0.932
0.5	8	0.937	11	0.956
0.6	6	0.961	6	0.969
0.7	4	0.976	5	0.980
0.8	3	0.988	3	0.987
0.9	0	0.988	1	0.989
1.0	1	0.992	2	0.993
1.1	0	0.992	1	0.996
1.2	1	0.996	1	0.998
1.3	1	1.000	1	1.000
1.4	0	1.000	0	1.000
1.5	0	1.000	0	1.000
Total	255		453	

Table 4-6: Industry Bounding and DCPP Unit 2 Cycle 9 Active Tube CPDF Growth Distributions.

Voltage Growth Per EFPY	DCPP-2 Cycle 9	Industry Bounding
<0	0.0353	0.0126
0	0.1545	0.0954
0.1	0.4945	0.3412
0.2	0.7903	0.6068
0.3	0.9007	0.8140
0.4	0.9316	0.8856
0.5	0.9558	0.9197
0.6	0.9691	0.9319
0.7	0.9801	0.9440
0.8	0.9868	0.9562
0.9	0.9890	0.9684
1	0.9934	0.9732
1.1	0.9956	0.9757
1.2	0.9978	0.9805
1.3	1.0000	0.9830
1.4	1.0000	0.9830
1.5	1.0000	0.9830
1.6	1.0000	0.9830
1.7	1.0000	0.9903
1.8	1.0000	0.9927
1.9	1.0000	0.9976
2	1.0000	0.9976
2.1	1.0000	0.9976
2.2	1.0000	0.9976
2.3	1.0000	0.9976
2.4	1.0000	0.9976
2.5	1.0000	0.9976
2.6	1.0000	0.9976
2.7	1.0000	0.9976
2.8	1.0000	0.9976
2.9	1.0000	0.9976
3	1.0000	0.9976
3.1	1.0000	0.9976
3.2	1.0000	0.9976
3.7	1.0000	0.9976
3.9	1.0000	0.9994
4.5	1.0000	0.9997
7	1.0000	0.9997
9.4	1.0000	1.0000

Table 4-7: NDE Uncertainty Distributions.

Analyst Uncertainty

Percent Variation	Cumulative Probability
-40.0%	0.00005
-38.0%	0.00011
-36.0%	0.00024
-34.0%	0.00048
-32.0%	0.00095
-30.0%	0.00179
-28.0%	0.00328
-26.0%	0.00580
-24.0%	0.00990
-22.0%	0.01634
-20.0%	0.02608
-18.0%	0.04027
-16.0%	0.06016
-14.0%	0.08704
-12.0%	0.12200
-10.0%	0.16581
-8.0%	0.21867
-6.0%	0.28011
-4.0%	0.34888
-2.0%	0.42302
0.0%	0.50000
2.0%	0.57698
4.0%	0.65112
6.0%	0.71989
8.0%	0.78133
10.0%	0.83419
12.0%	0.87800
14.0%	0.91296
16.0%	0.93984
18.0%	0.95973
20.0%	0.97392
22.0%	0.98366
24.0%	0.99010
26.0%	0.99420
28.0%	0.99672
30.0%	0.99821
32.0%	0.99905
34.0%	0.99952
36.0%	0.99976
38.0%	0.99989
40.0%	0.99995

Std Deviation = 10.3%
Mean = 0.0%
No Cutoff

Acquisition Uncertainty

Percent Variation	Cumulative Probability
<-15.0%	0.00000
-15.0%	0.01606
-14.0%	0.02275
-13.0%	0.03165
-12.0%	0.04324
-11.0%	0.05804
-10.0%	0.07656
-9.0%	0.09927
-8.0%	0.12655
-7.0%	0.15866
-6.0%	0.19568
-5.0%	0.23753
-4.0%	0.28385
-3.0%	0.33412
-2.0%	0.38755
-1.0%	0.44320
0.0%	0.50000
1.0%	0.55680
2.0%	0.61245
3.0%	0.66588
4.0%	0.71615
5.0%	0.76247
6.0%	0.80432
7.0%	0.84134
8.0%	0.87345
9.0%	0.90073
10.0%	0.92344
11.0%	0.94196
12.0%	0.95676
13.0%	0.96835
14.0%	0.97725
15.0%	0.98394
>15.0%	1.00000

Std Deviation = 7.0%
Mean = 0.0%
Cutoff = +/- 15.0%

Table 4-8: Projected EOC-10 Voltage Distributions.

Voltage Bin	Projected No. of Indications at EOC10			
	SG 2-1	SG 2-2	SG 2-3	SG 2-4
0.1	0.0982	0.1833	0.0217	0.0132
0.2	2.1719	1.4086	0.6022	0.4889
0.3	7.0241	4.3593	2.6298	3.5376
0.4	13.4823	8.4282	5.6214	13.5007
0.5	20.4804	12.2942	8.6468	29.0110
0.6	24.4314	13.7909	11.3975	46.8621
0.7	23.3101	13.2365	11.4365	57.6301
0.8	19.7832	10.7765	10.2318	58.4478
0.9	15.4008	8.3288	8.3197	52.0781
1	11.7380	6.0900	6.4910	43.1866
1.1	8.8361	4.3547	4.9147	34.6052
1.2	6.6465	3.1830	3.7593	27.8162
1.3	4.8502	2.5475	2.9041	22.9405
1.4	3.4954	2.0649	2.2507	19.2555
1.5	2.6063	1.5630	1.8384	16.2955
1.6	1.9818	1.1540	1.5419	13.5148
1.7	1.4932	0.8472	1.2549	10.7735
1.8	1.1110	0.6129	1.0138	8.3243
1.9	0.8427	0.4531	0.8281	6.3648
2	0.6761	0.3657	0.7174	5.1009
2.1	0.5677	0.3211	0.6407	4.3177
2.2	0.4722	0.2529	0.5869	3.7937
2.3	0.3473	0.1883	0.5061	3.2387
2.4	0.2324	0.1306	0.4181	2.6083
2.5	0.1436	0.0996	0.3290	2.0050
2.6	0.1214	0.0896	0.2602	1.5144
2.7	0.1558	0.1174	0.2319	1.2459
2.8	0.1919	0.1658	0.2076	1.1571
2.9	0.2196	0.1771	0.1891	1.1154
3	0.2230	0.1848	0.1805	1.0858
3.1	0.1956	0.1864	0.1518	1.0073
3.2	0.1550	0.1437	0.1203	0.8530
3.3	0.1092	0.1062	0.0931	0.6682
3.4	0.0722	0.0865	0.0641	0.4844
3.5	0.0456	0.0636	0.0440	0.3458
3.6	0.0299	0.0460	0.0315	0.2570
3.7	0.0183	0.0354	0.0230	0.1953
3.8	0.0096	0.0274	0.0164	0.1489
3.9	0.0048	0.0205	0.0124	0.1134
4	0.0023	0.0146	0.0094	0.0855
4.1	0.0011	0.0103	0.0072	0.0622
4.2	0.0005	0.0073	0.0056	0.0445
4.3	0.0002	0.0056	0.0045	0.0328
4.4	0.0001	0.0044	0.0035	0.0254
4.5	0.0000	0.0032	0.0032	0.0202
>4.5	0.2207	0.1400	0.1280	0.8346
Total	174.00	98.67	90.69	497.01

Table 4-9: EPRI-Recommended Limiting Growth Distribution for Indications in Deplugged Tubes during First Cycle of Operation.

Delta Volts	Ref.7 - Limiting		
	No. of Obs	CPDF	Normal
-0.4	0	0.000	0.000
-0.3	0	0.000	0.000
-0.2	0	0.000	0.000
-0.1	0	0.000	0.000
0.0	2	0.018	0.018
0.1	20	0.198	0.180
0.2	24	0.414	0.216
0.3	17	0.568	0.153
0.4	9	0.649	0.081
0.5	9	0.730	0.081
0.6	4	0.766	0.036
0.7	5	0.811	0.045
0.8	5	0.856	0.045
0.9	5	0.901	0.045
1.0	1	0.910	0.009
1.1	0	0.910	0.000
1.2	2	0.928	0.018
1.3	1	0.937	0.009
1.4	0	0.937	0.000
1.5	0	0.937	0.000
1.6	0	0.937	0.000
1.7	3	0.964	0.027
1.8	1	0.973	0.009
1.9	2	0.991	0.018
2.0	0	0.991	0.000
2.1	0	0.991	0.000
2.2	0	0.991	0.000
2.3	0	0.991	0.000
2.4	0	0.991	0.000
2.5	0	0.991	0.000
2.6	0	0.991	0.000
2.7	0	0.991	0.000
2.8	0	0.991	0.000
2.9	0	0.991	0.000
3.0	0	0.991	0.000
3.1	0	0.991	0.000
3.2	0	0.991	0.000
3.8	1	1.000	0.009
Total	111		

Table 4-10: SG Composite Combined Projected Average Growth Distribution for Cycle 10 (used for projected EOC-10 for SG 2-1, 2-2, and 2-3).

Delta Volts	Combined Average SG Growth Rate			
	Deplugged (per Table 4-9)	Active (2R9 Composite)	Combined	Combined - CPDF
0.0	1.4	70	72.6	0.135
0.1	14.1	154	170.4	0.453
0.2	16.9	134	152.8	0.737
0.3	11.9	50	62.5	0.854
0.4	6.3	14	20.4	0.892
0.5	6.3	11	17.4	0.924
0.6	2.8	6	8.8	0.940
0.7	3.5	5	8.5	0.956
0.8	3.5	3	6.5	0.968
0.9	3.5	1	4.4	0.976
1.0	0.7	2	2.7	0.982
1.1	0.0	1	1.0	0.983
1.2	1.4	1	2.4	0.988
1.3	0.7	1	1.7	0.991
1.4	0.0	0	0.0	0.991
1.5	0.0	0	0.0	0.991
1.6	0.0	0	0.0	0.991
1.7	2.1	0	2.1	0.995
1.8	0.7	0	0.7	0.996
1.9	1.4	0	1.4	0.999
2.0	0.0	0	0.0	0.999
2.1	0.0	0	0.0	0.999
2.2	0.0	0	0.0	0.999
2.3	0.0	0	0.0	0.999
2.4	0.0	0	0.0	0.999
2.5	0.0	0	0.0	0.999
2.6	0.0	0	0.0	0.999
2.7	0.0	0	0.0	0.999
2.8	0.0	0	0.0	0.999
2.9	0.0	0	0.0	0.999
3.0	0.0	0	0.0	0.999
3.1	0.0	0	0.0	0.999
3.2	0.0	0	0.0	0.999
3.9	0.7	0	0.7	1.000
Total	78.0	453	537.0	

Table 4-11: Combined Projected Cycle 10 Growth Rate Distribution for SG 2-1 (not used in Monte Carlo analysis - for information only).

Delta Volts	Combined Growth Rate for SG 2-1			
	Deplugged (per Table 4-9)	Active (SG Specific)	Combined	Combined - CPDF
0.0	0.2	38	40.6	0.376
0.1	2.0	32	35.7	0.706
0.2	2.4	17	20.0	0.892
0.3	1.7	4	5.6	0.944
0.4	0.9	2	2.9	0.971
0.5	0.9	0	0.7	0.977
0.6	0.4	0	0.3	0.980
0.7	0.5	0	0.4	0.984
0.8	0.5	0	0.4	0.988
0.9	0.5	0	0.4	0.992
1.0	0.1	0	0.1	0.992
1.1	0.0	0	0.0	0.992
1.2	0.2	0	0.2	0.994
1.3	0.1	0	0.1	0.995
1.4	0.0	0	0.0	0.995
1.5	0.0	0	0.0	0.995
1.6	0.0	0	0.0	0.995
1.7	0.3	0	0.2	0.997
1.8	0.1	0	0.1	0.998
1.9	0.2	0	0.2	0.999
2.0	0.0	0	0.0	0.999
2.1	0.0	0	0.0	0.999
2.2	0.0	0	0.0	0.999
2.3	0.0	0	0.0	0.999
2.4	0.0	0	0.0	0.999
2.5	0.0	0	0.0	0.999
2.6	0.0	0	0.0	0.999
2.7	0.0	0	0.0	0.999
2.8	0.0	0	0.0	0.999
2.9	0.0	0	0.0	0.999
3.0	0.0	0	0.0	0.999
3.1	0.0	0	0.0	0.999
3.2	0.0	0	0.0	0.999
3.9	0.1	0	0.1	1.000
Total	11.0	93	108.0	

Table 4-12: Combined Projected Cycle 10 Growth Rate Distribution for SG 2-2 (not used in Monte Carlo analysis - for information only).

Delta Volts	Combined Growth Rate for SG 2-2			
	Deplugged (per Table 4-9)	Active (SG Specific)	Combined	Combined - CPDF
0.0	0.1	12	12.1	0.202
0.1	1.3	22	23.3	0.590
0.2	1.5	14	15.5	0.848
0.3	1.1	2	3.1	0.900
0.4	0.6	1	1.6	0.926
0.5	0.6	1	1.6	0.952
0.6	0.3	0	0.3	0.956
0.7	0.3	0	0.3	0.961
0.8	0.3	0	0.3	0.967
0.9	0.3	0	0.3	0.972
1.0	0.1	0	0.1	0.973
1.1	0.0	1	1.0	0.989
1.2	0.1	0	0.1	0.992
1.3	0.1	0	0.1	0.993
1.4	0.0	0	0.0	0.993
1.5	0.0	0	0.0	0.993
1.6	0.0	0	0.0	0.993
1.7	0.2	0	0.2	0.996
1.8	0.1	0	0.1	0.997
1.9	0.1	0	0.1	0.999
2.0	0.0	0	0.0	0.999
2.1	0.0	0	0.0	0.999
2.2	0.0	0	0.0	0.999
2.3	0.0	0	0.0	0.999
2.4	0.0	0	0.0	0.999
2.5	0.0	0	0.0	0.999
2.6	0.0	0	0.0	0.999
2.7	0.0	0	0.0	0.999
2.8	0.0	0	0.0	0.999
2.9	0.0	0	0.0	0.999
3.0	0.0	0	0.0	0.999
3.1	0.0	0	0.0	0.999
3.2	0.0	0	0.0	0.999
3.9	0.1	0	0.1	1.000
Total	7.0	53	60.0	

Table 4-13: Combined Projected Cycle 10 Growth Rate Distribution for SG 2-3 (not used in Monte Carlo analysis - for information only).

Delta Volts	Combined Growth Rate for SG 2-3			
	Deplugged (per Table 4-9)	Active (SG Specific)	Combined	Combined - CPDF
0.0	0.1	4	4.0	0.071
0.1	1.1	16	16.5	0.365
0.2	1.3	20	20.5	0.731
0.3	0.9	5	5.7	0.833
0.4	0.5	2	2.4	0.877
0.5	0.5	2	2.4	0.920
0.6	0.2	0	0.2	0.923
0.7	0.3	1	1.2	0.945
0.8	0.3	0	0.3	0.950
0.9	0.3	1	1.2	0.972
1.0	0.1	1	1.0	0.990
1.1	0.0	0	0.0	0.990
1.2	0.1	0	0.1	0.992
1.3	0.1	0	0.1	0.993
1.4	0.0	0	0.0	0.993
1.5	0.0	0	0.0	0.993
1.6	0.0	0	0.0	0.993
1.7	0.2	0	0.2	0.996
1.8	0.1	0	0.1	0.997
1.9	0.1	0	0.1	0.999
2.0	0.0	0	0.0	0.999
2.1	0.0	0	0.0	0.999
2.2	0.0	0	0.0	0.999
2.3	0.0	0	0.0	0.999
2.4	0.0	0	0.0	0.999
2.5	0.0	0	0.0	0.999
2.6	0.0	0	0.0	0.999
2.7	0.0	0	0.0	0.999
2.8	0.0	0	0.0	0.999
2.9	0.0	0	0.0	0.999
3.0	0.0	0	0.0	0.999
3.1	0.0	0	0.0	0.999
3.2	0.0	0	0.0	0.999
3.9	0.1	0	0.1	1.000
Total	6.0	52	56.0	

Table 4-14: Combined Projected Cycle 10 Growth Rate Distribution for SG 2-4 (used for projected EOC-10 for SG 2-4).

Delta Volts	Combined Growth Rate for SG 2-4			
	Deplugged (per Table 4-9)	Active (SG Specific)	Combined	Combined - CPDF
0.0	1.0	16	17.2	0.055
0.1	9.7	84	95.0	0.359
0.2	11.7	83	96.0	0.665
0.3	8.3	39	47.9	0.818
0.4	4.4	9	13.5	0.862
0.5	4.4	8	12.5	0.901
0.6	1.9	6	8.0	0.927
0.7	2.4	4	6.5	0.948
0.8	2.4	3	5.5	0.965
0.9	2.4	0	2.4	0.973
1.0	0.5	1	1.5	0.978
1.1	0.0	0	0.0	0.978
1.2	1.0	1	2.0	0.984
1.3	0.5	1	1.5	0.989
1.4	0.0	0	0.0	0.989
1.5	0.0	0	0.0	0.989
1.6	0.0	0	0.0	0.989
1.7	1.5	0	1.5	0.994
1.8	0.5	0	0.5	0.995
1.9	1.0	0	1.0	0.998
2.0	0.0	0	0.0	0.998
2.1	0.0	0	0.0	0.998
2.2	0.0	0	0.0	0.998
2.3	0.0	0	0.0	0.998
2.4	0.0	0	0.0	0.998
2.5	0.0	0	0.0	0.998
2.6	0.0	0	0.0	0.998
2.7	0.0	0	0.0	0.998
2.8	0.0	0	0.0	0.998
2.9	0.0	0	0.0	0.998
3.0	0.0	0	0.0	0.998
3.1	0.0	0	0.0	0.998
3.2	0.0	0	0.0	0.998
3.9	0.5	0	0.5	1.000
Total	54.0	255	313.0	

Figure 4-1: SG 2-1 2R9 As-found and BOC-10 Voltage Distributions

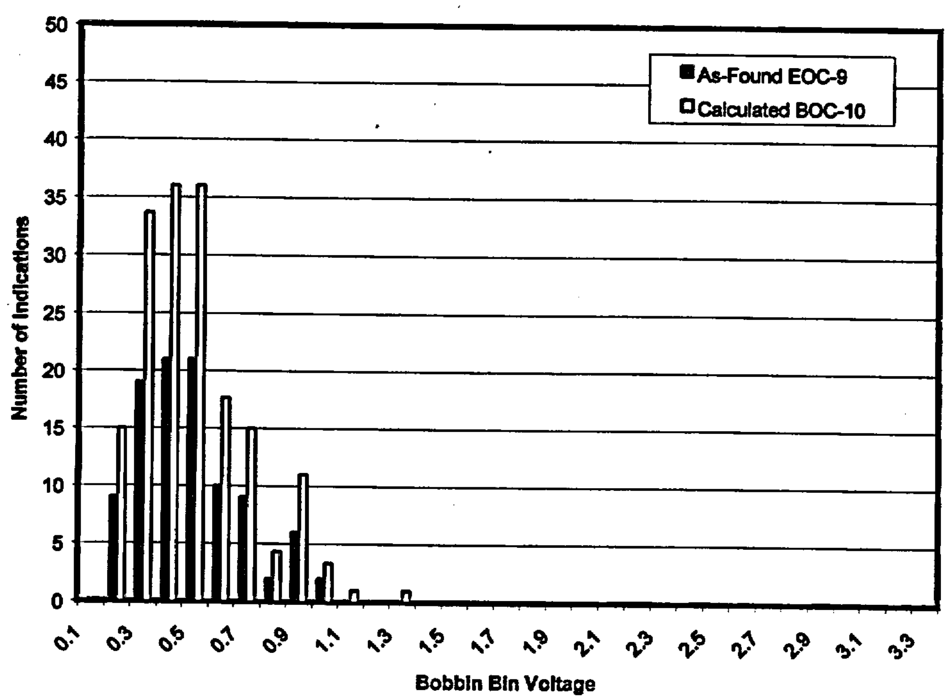


Figure 4-2: SG 2-2 2R9 As-found and BOC-10 Voltage Distributions

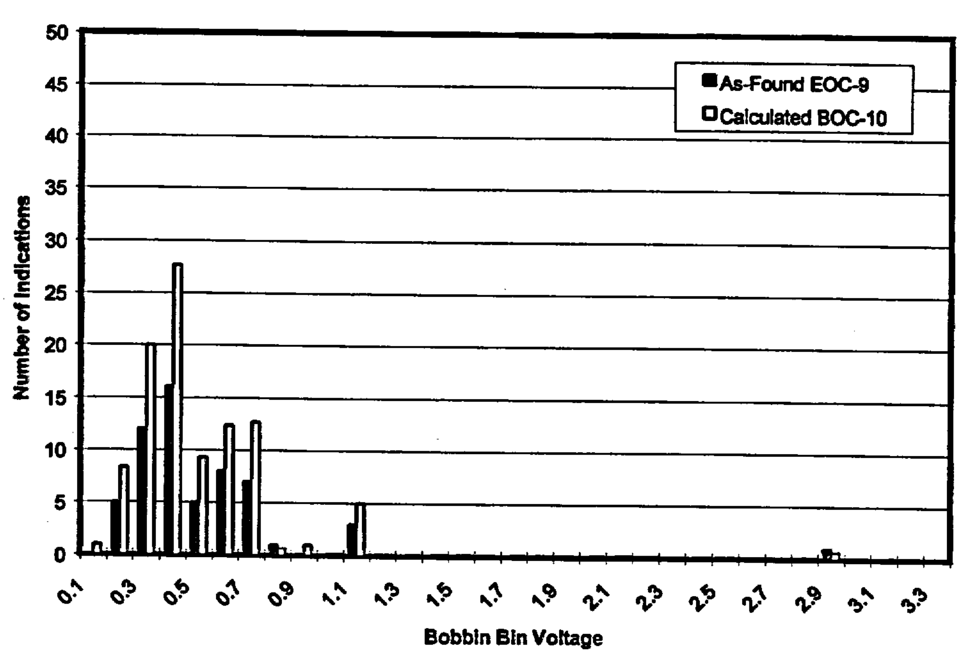


Figure 4-3: SG 2-3 2R9 As-found and BOC-10 Voltage Distributions

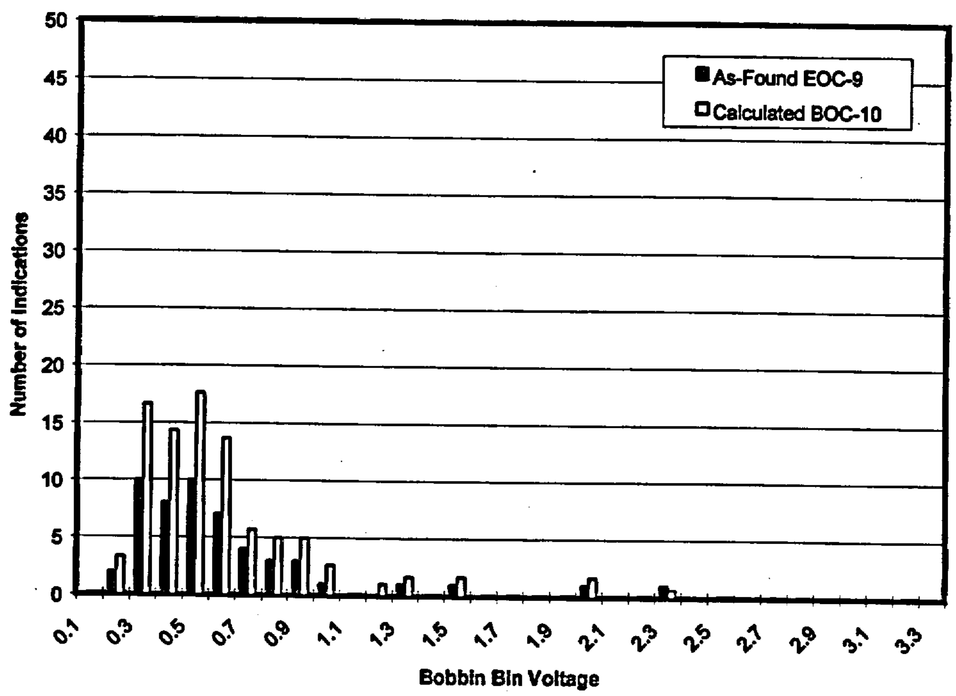


Figure 4-4: SG 2-4 2R9 As-found and BOC-10 Voltage Distributions

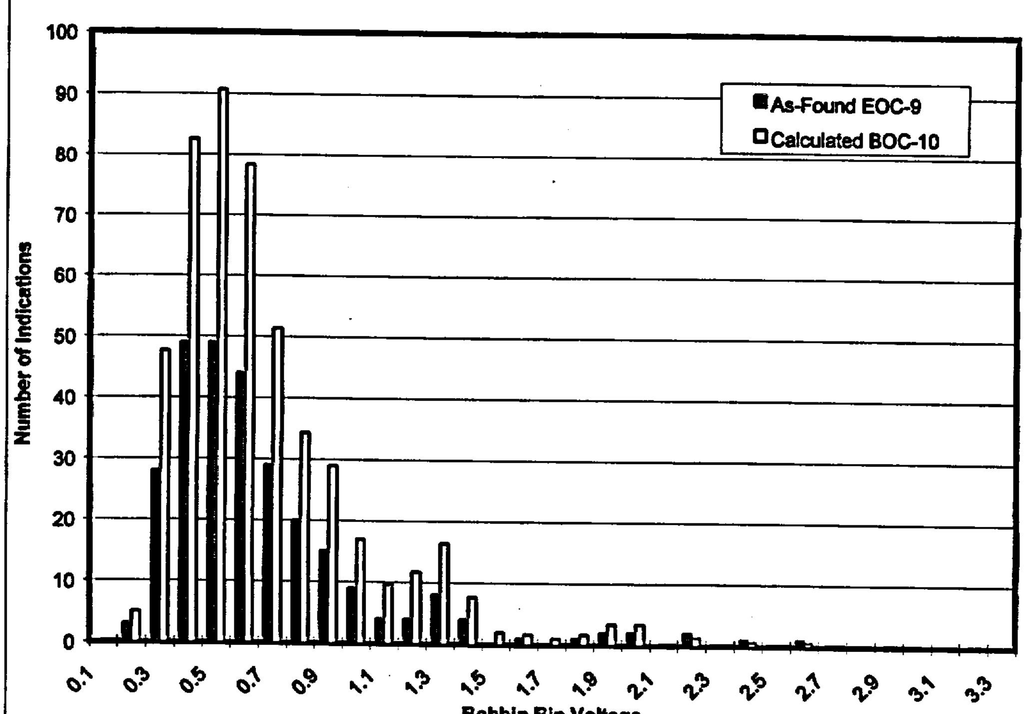


Figure 4-5: SG 2-1 & 2-2 Repaired Tube Voltage Distributions

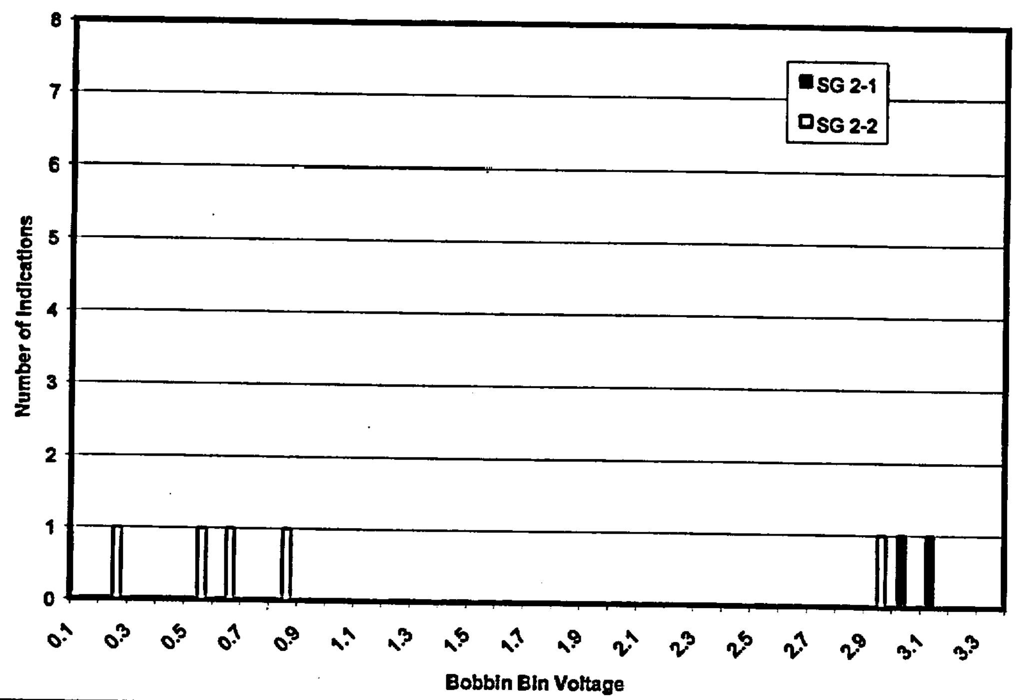


Figure 4-6: SG 2-3 & 2-4 Repaired Tube Voltage Distributions

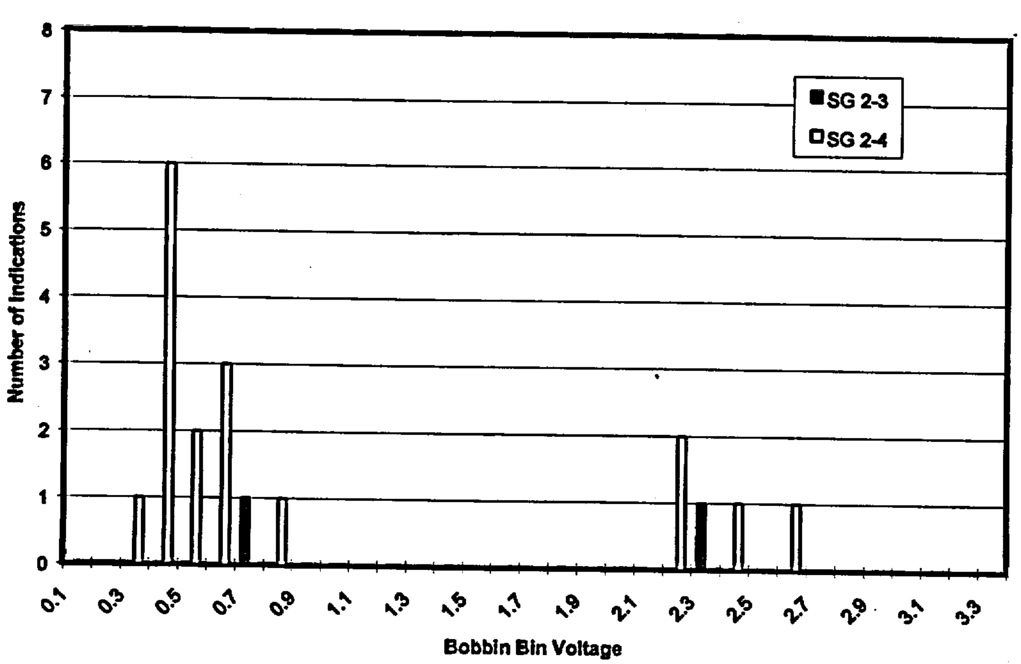


Figure 4-7: SG 2-1 & 2-2 Voltage Distributions of Confirmed ODSCC and Uninspected DOS Indications Remaining in Service for Cycle 10

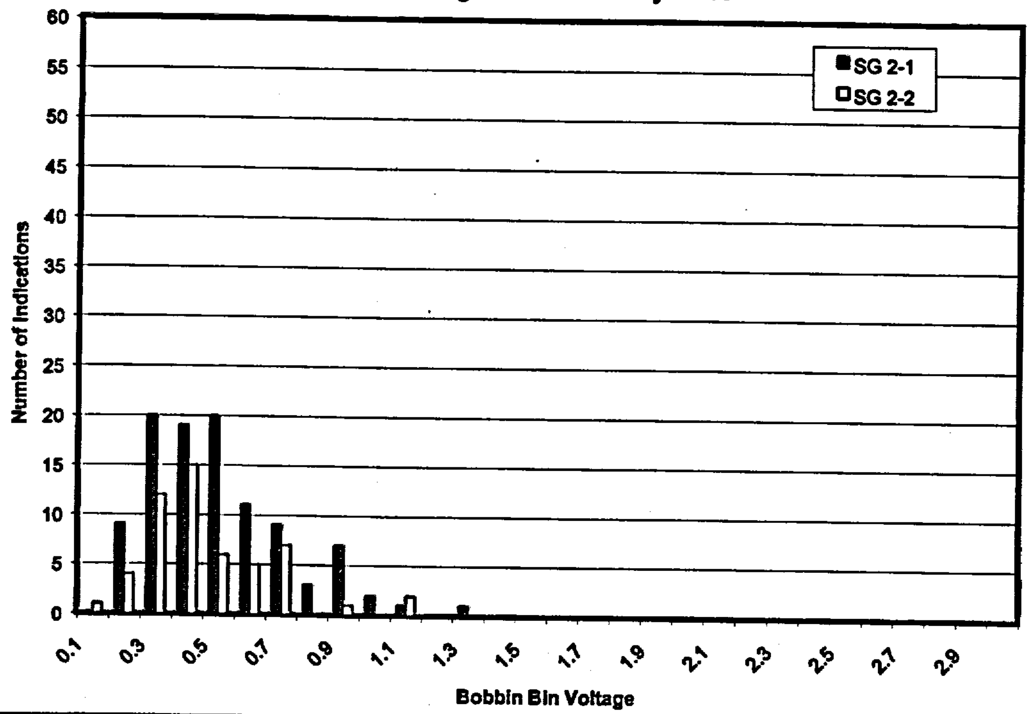


Figure 4-8: SG 2-3 & 2-4 Voltage Distributions of Confirmed ODSCC and Uninspected DOS Indications Remaining in Service for Cycle 10

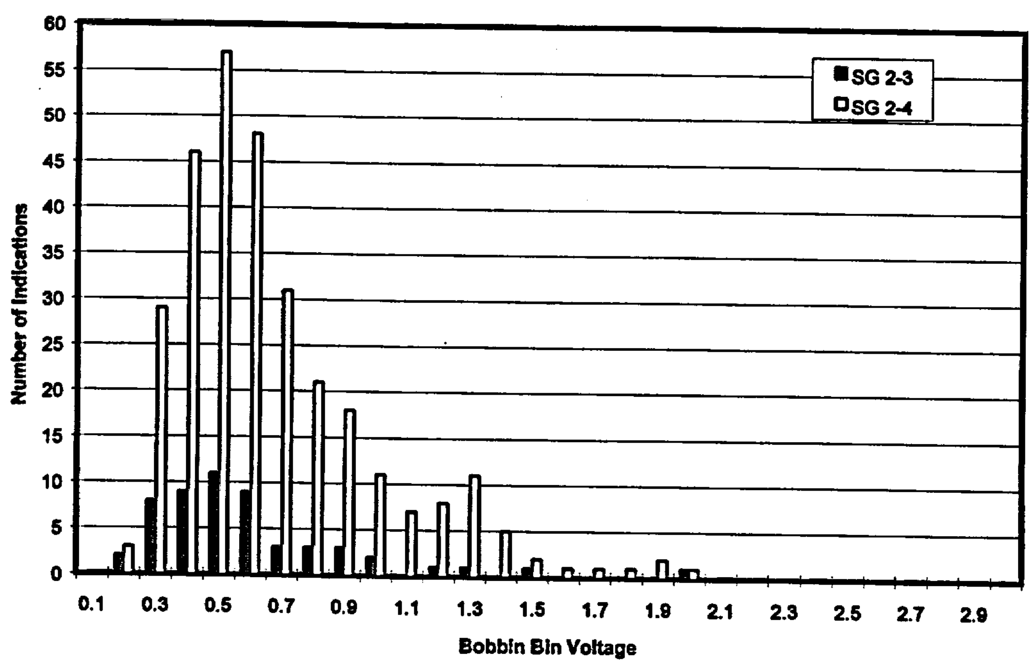


Figure 4-9: SG 2-1 & 2-2 Voltage Distributions of All DOS Indications Remaining in Service for Cycle 10

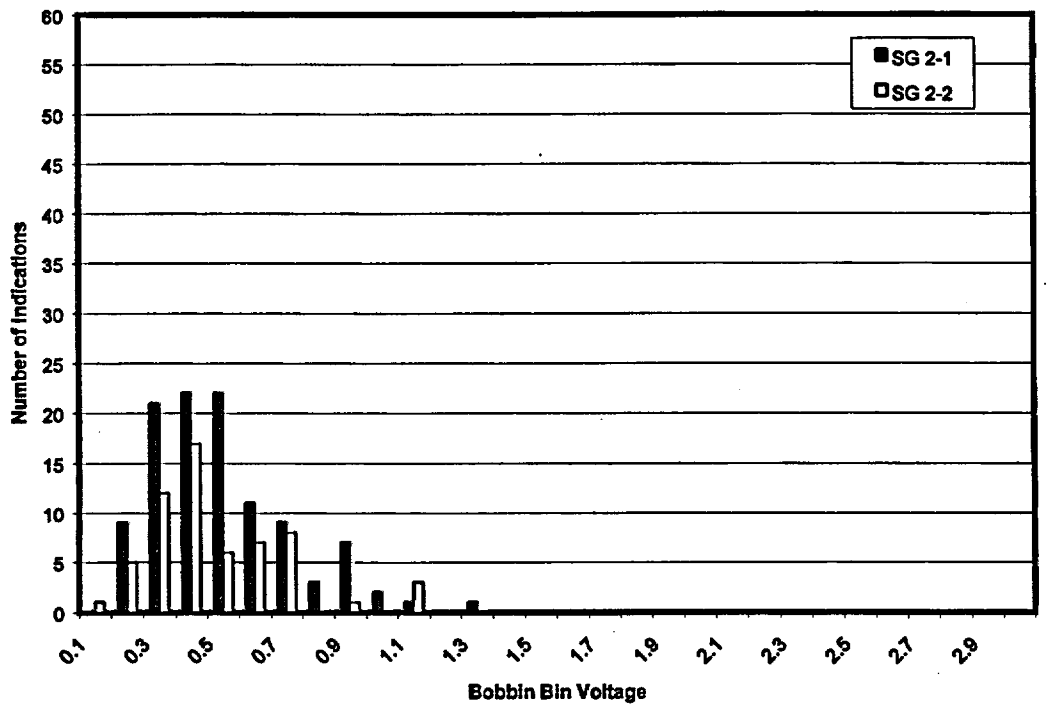


Figure 4-10: SG 2-3 & 2-4 Voltage Distributions of All DOS Indications Remaining in Service for Cycle 10

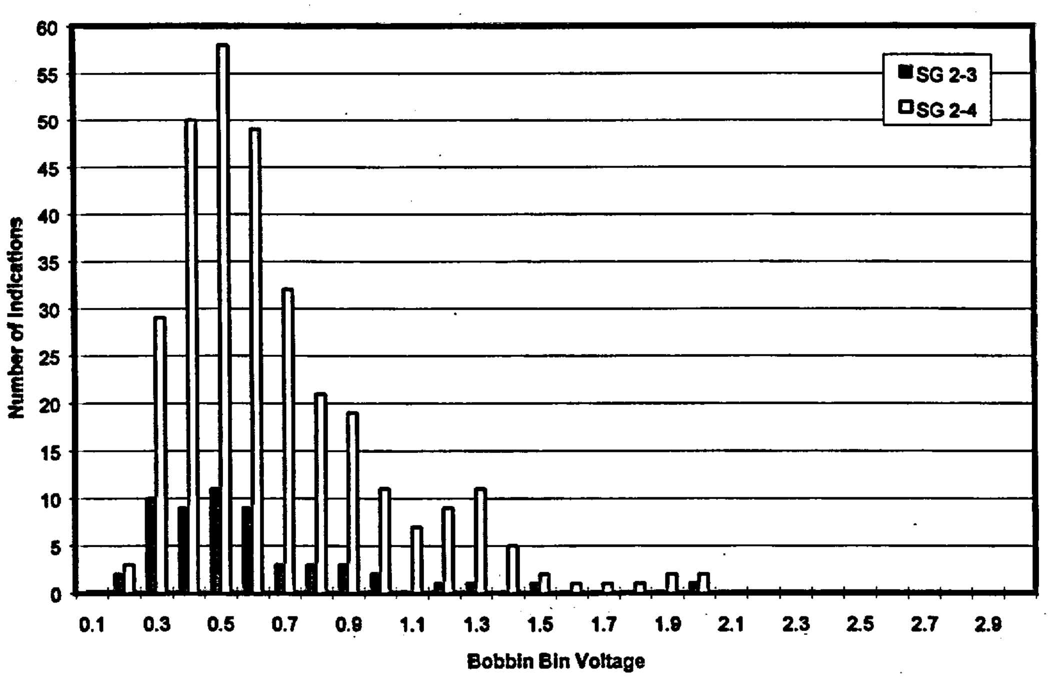


Figure 4-11: SG 2-1 & 2-2 Active Tube Delta Voltage Per EFPY Growth Distributions of Bobbin Indications Detected During 2R9

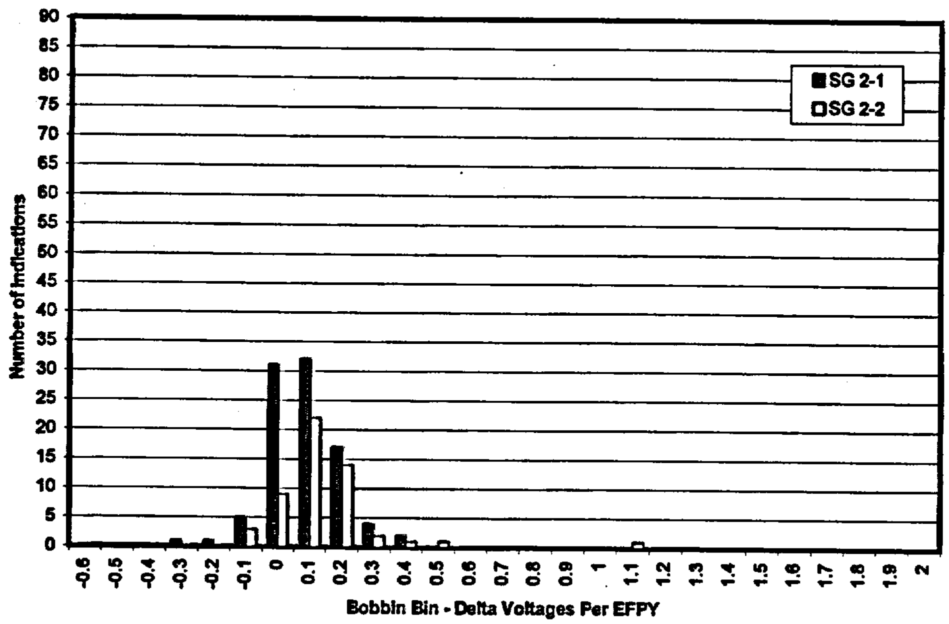


Figure 4-12: SG 2-3 & 2-4 Active Tube Delta Voltage Per EFPY Growth Distributions of Bobbin Indications Detected During 2R9

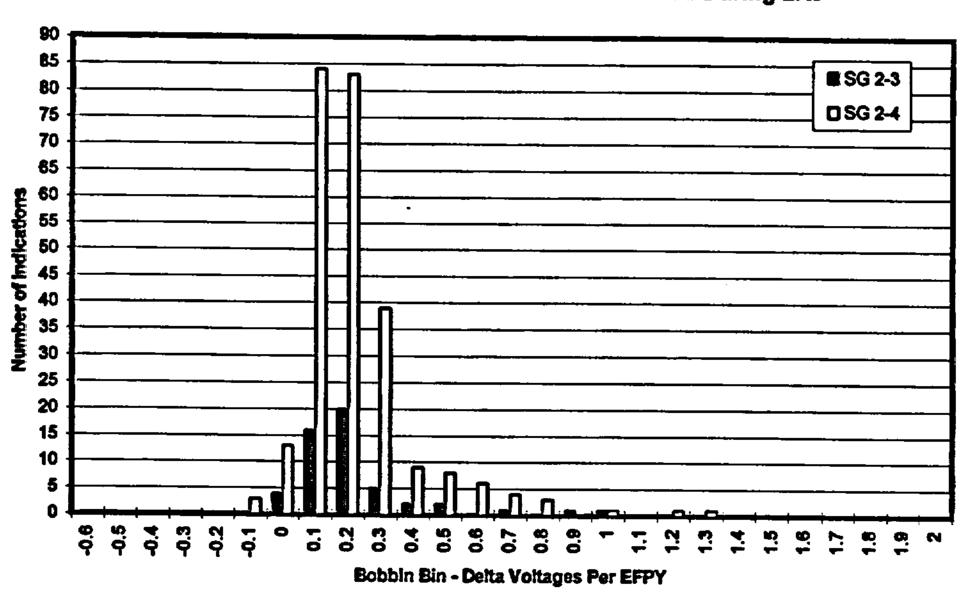


Figure 4-13: DCPP Unit 2 Cycle 9 Growth Rate (CPDF) Curve Compared with the Industry-Bounding Curve

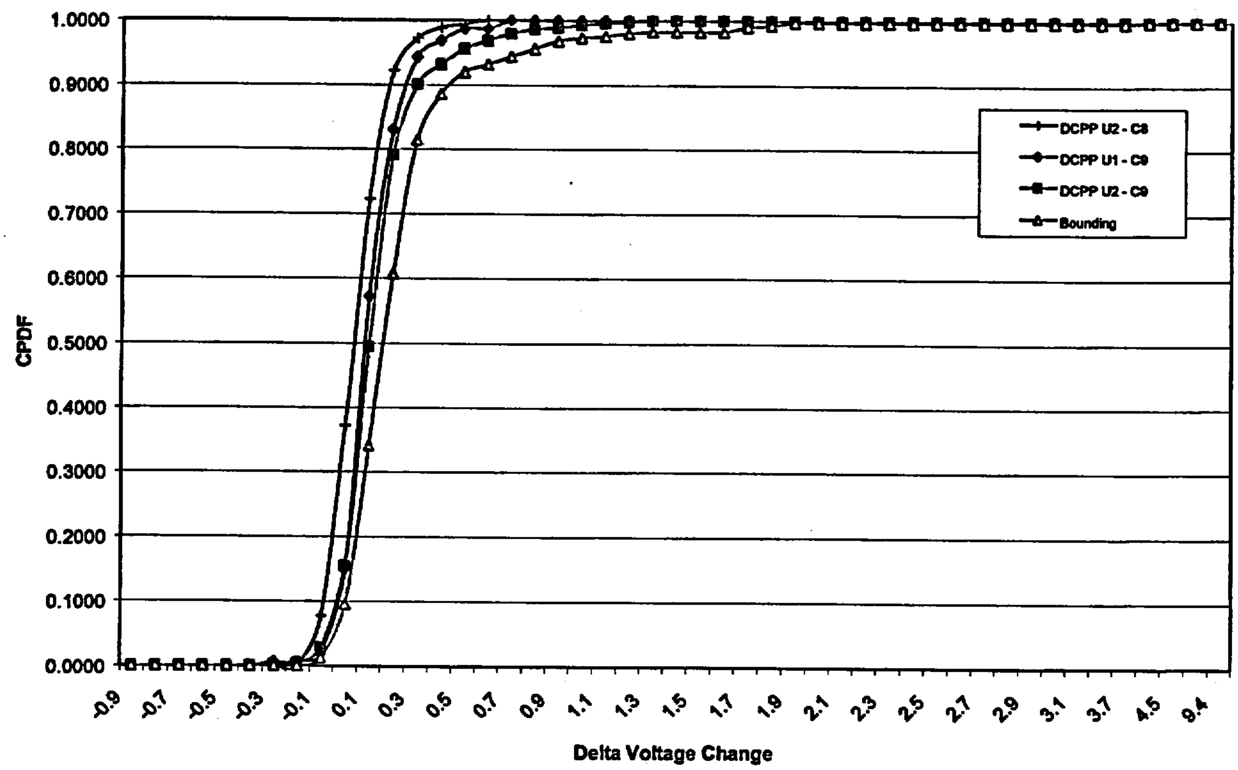


Figure 4-14: SG Combined Growth Rates for 2R9 Compared to the Bounding and Deplugged Cumulative Growth Distributions

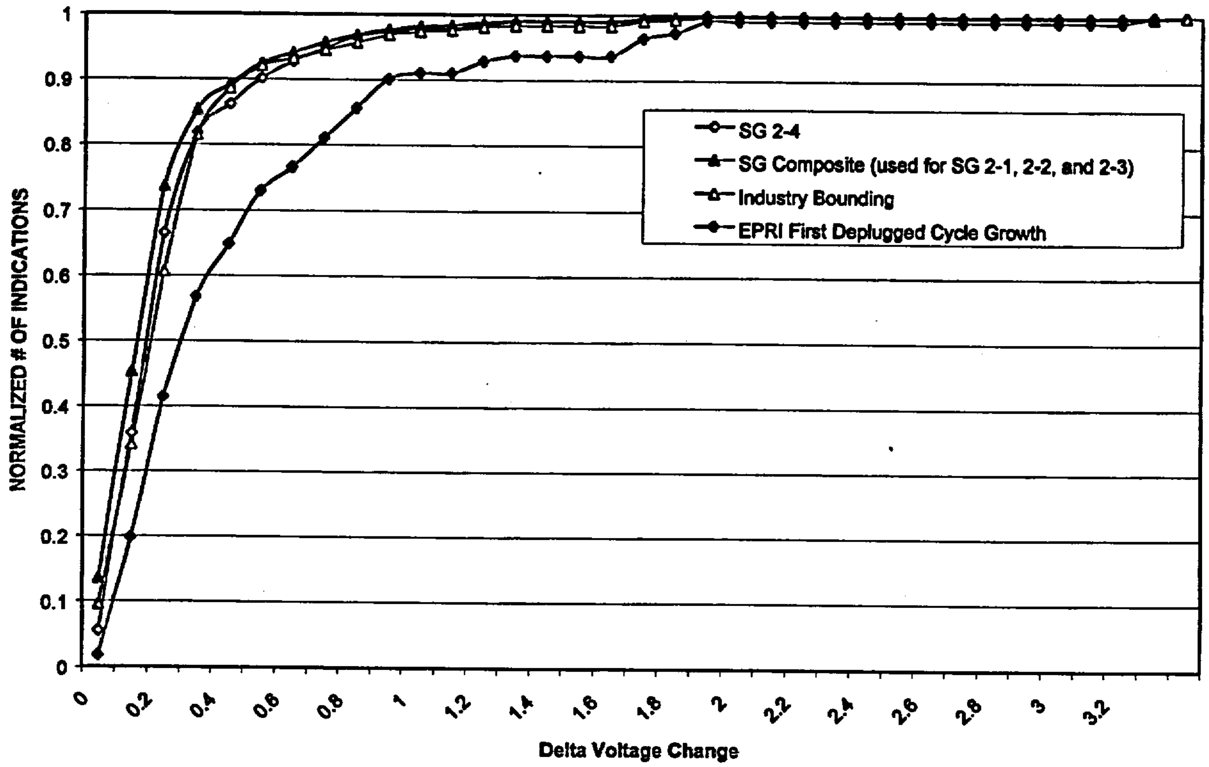
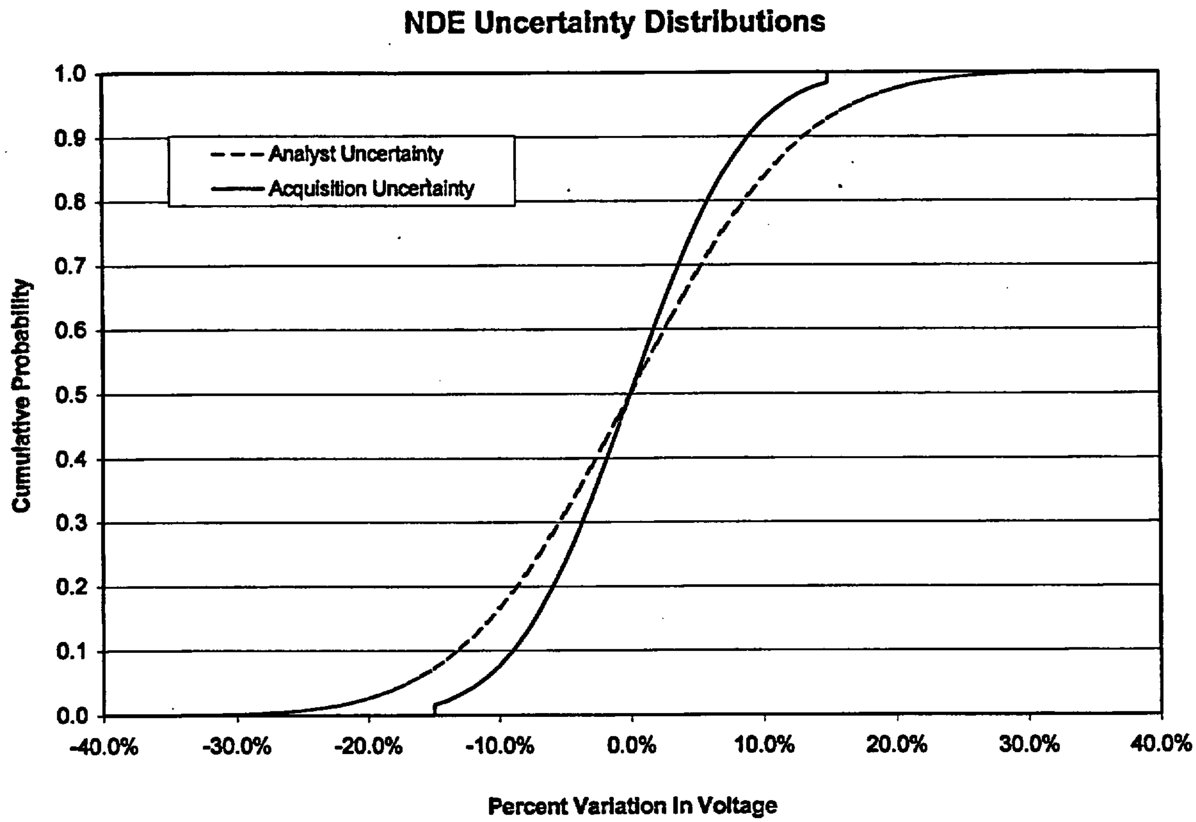


Figure 4-15



NDE Uncertainty Distributions
Analyst Uncertainty
Acquisition Uncertainty
Cumulative Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-40.0%
-30.0%
-20.0%
-10.0%
0.0%
10.0%
20.0%
30.0%
40.0%
Percent Variation In Voltage

Figure 4-16: SG 2-1 Projected EOC-10 Voltage Distributions

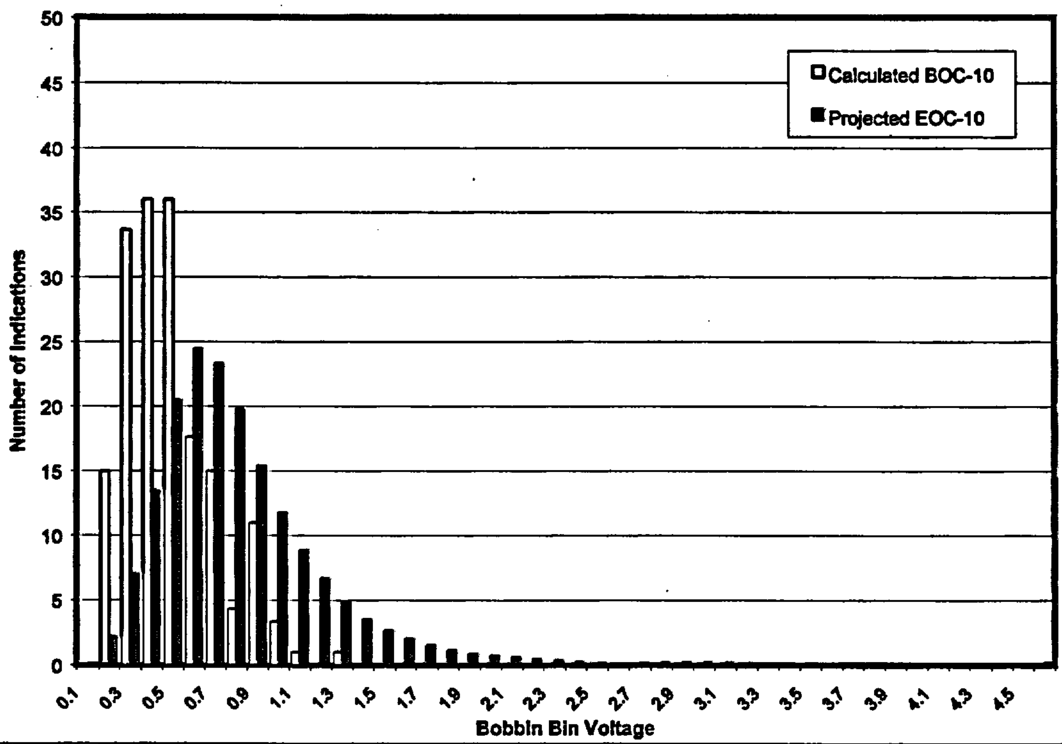


Figure 4-17: SG 2-2 Projected EOC-10 Voltage Distributions

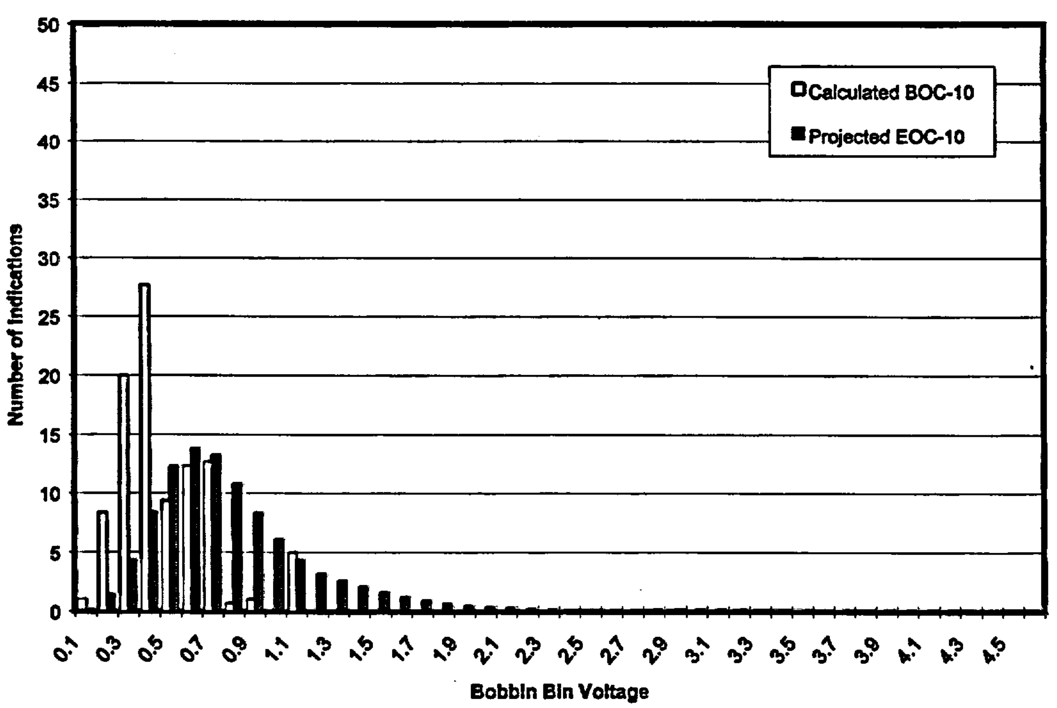


Figure 4-18: SG 2-3 Projected EOC-10 Voltage Distributions

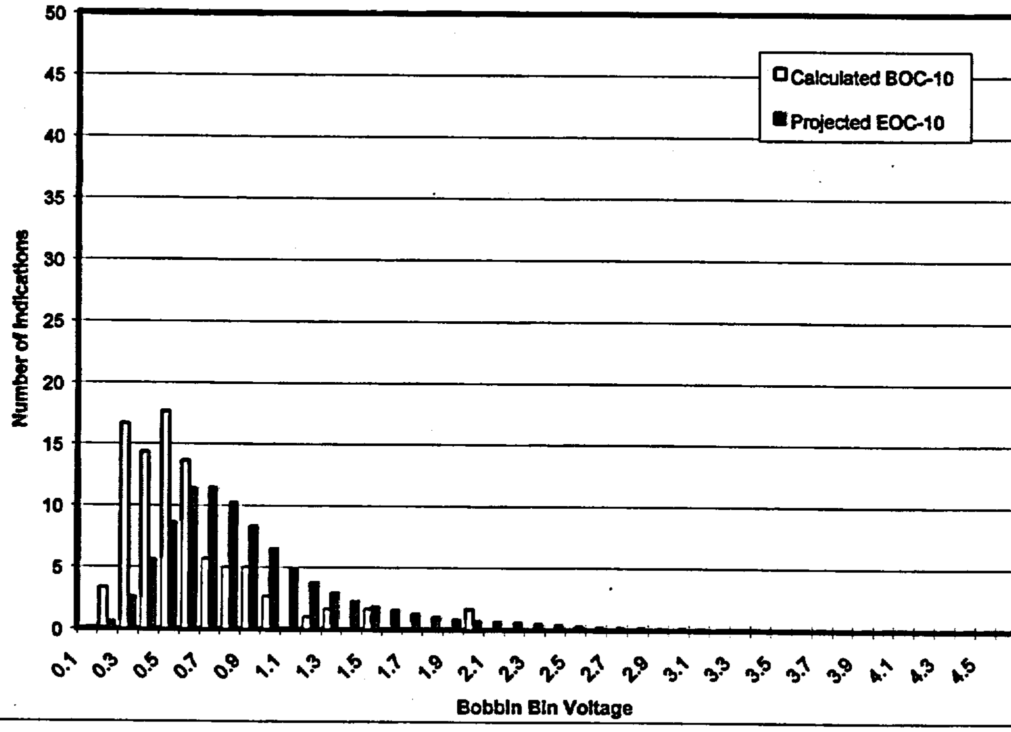
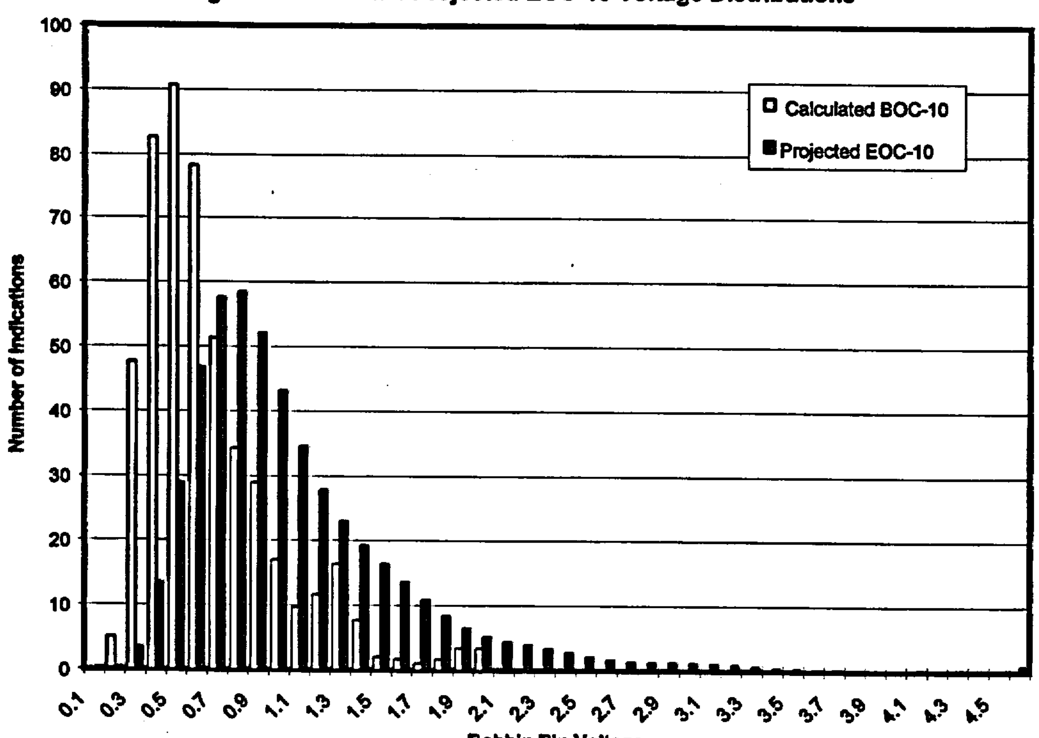


Figure 4-19: SG 2-4 Projected EOC-10 Voltage Distributions



5.0 Database Applied for Leak and Burst Correlations

The leak and burst correlations utilized in the analyses presented in this report are based on the Addendum 3 1999 Database Update (Ref. 7) for the voltage-based repair criteria for 7/8 inch tubing. The leak rate correlations used were developed for a MSLB delta P of 2560 psi. The correlations have been developed specifically for the evaluation of ODSCC indications at TSP locations in Model 51 steam generators and relate Bobbin voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates to assess end of next cycle structural integrity.

5.1 Conditional Probability of Burst

For the burst pressure versus voltage correlation, the database contained in Ref. 7 meets all GL 95-05 requirements and was used in these calculations. Material properties were also considered as part of the calculations and were obtained from Ref. 6. The FTI Monte Carlo computer code was utilized to predict the POB at the end of cycle 10 based upon the input parameters shown in Table 5-1 (from Ref. 7, Table 6-6). This simulation follows the statistical methods presented in Ref. 6.

Table 5-1
Tube Burst Pressure vs. Bobbin Amplitude Correlation
$P_B = \alpha_0 + \alpha_1 \log(Volts)$

Parameter	Database	Adjusted Input(1)
α_0	7.57661	8.261536
α_1	-2.39816	-2.61495
r^2	82.3%	82.3%
σ_{Error}	0.82389	0.89837
N (data pairs)	91	91
p Value for α_2	$1.60\text{x}10^{-35}$	$1.60\text{x}10^{-35}$
Reference σ_f	68.78	75

Note:
(1) The slope and intercept coefficients and the standard error value from Ref. 7 were adjusted for a reference flow stress of 75.0 ksi by multiplying those input terms by 1.0904.

5.2 Conditional Leak Rate

Ref. 7 presents the results of the regression analysis for the voltage-dependent leak rate correlation using the updated leak rate database for 7/8" tubes mentioned above. It is shown that the one-sided p-value for the slope parameter in the voltage dependent leak rate correlation is 3.5% which is below the 5% threshold for an acceptable correlation specified in Generic Letter 95-05.

The methodology used in the calculation of these parameters is consistent with the NRC criteria in Ref. 1. The POL and leak rate correlation parameters used in this analysis are shown in Tables 5-2 and 5-3. The inputs are taken directly from Ref. 7 Table 6-7 and Ref. 18 Table 6-7, respectively.

Table 5-2
7/8" Tube Probability of Leak Correlation (2560 psi)
$$Pr(Leak) = \{1 + e^{-[\beta 1+\beta 2 \log(V)]}\}^{-1}$$

Parameter	Database
β_1	-4.31236
β_2	4.21125
V_{11} (1)	0.67152
V_{12}	-0.59145
V_{22}	0.59172
DoF (2)	137
Deviance	78.81
Pearson SD	75.0%

Notes:

(1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation.
(2) Degrees of freedom.

Table 5-3
Leak Rate Database for 7/8" Tube ARC Applications

$$Q = 10^{\left(b_3 + b_4 \times \log(volts) \right)}$$

Parameter	Database
Intercept, b_3	-0.526882
Slope, b_4	0.987179
Index of Deter, r^2	11.7%
Residuals, σ_{Error} (b_5)	0.808109
Data Pairs, N	29
Mean of Log(V)	1.15437
SS of Log(V)	2.39739
p Value for b_4	3.5%

6.0 2R9 Evaluation of POPCD for EOC-8

The inspection results at EOC-9 permit an evaluation of the probability of detection during the prior cycle (POPCD), i.e., 2R8. For ARC applications, the important indications are those that could significantly contribute to the EOC probability of burst and leak rate. These significant indications are expected to be detected by Bobbin and confirmed by Plus Point inspection. Thus, the population of interest for the ARC POD review is the EOC-9 Plus Point confirmed indications that either were or were not detected during the prior inspection. The POPCD for 2R8 can then be defined as:

$$POPCD_{(EOC-8)} = \frac{[(EOC-8)confirmed\ @\ EOC-9] + [(EOC-8)confirmed\ \&\ repaired]}{\{Numerator\} + [(EOC-9)confirmed\ \&\ new]}$$

The POPCD for 2R8 is evaluated for the EOC-8 voltages that were generated during the voltage "look ups" for growth during 2R9. The indications at EOC-8 that were Plus Point confirmed and plugged are also included. It is appropriate to include plugged tubes for ARC applications since the POD adjustments to define the BOC distribution are applied prior to reduction of the EOC plugged indications. It should be noted that the POPCD definition includes all new EOC-9 indications not reported in the EOC-8 inspection. The new indications include EOC-8 indications present at detectable levels but not reported (i.e., indications present at EOC-8 below detectable levels) and indications that initiated during Cycle 9. Thus, this definition, by including newly initiated indications, differs from the traditional POD definition. Since newly initiated indications are appropriate for the ARC, POPCD may be an acceptable definition that eliminates the need to adjust the traditional POD for new indications.

Also note that the above definition for POPCD is based on the premise that all indications which contribute significantly are confirmed. However, since only a fraction of the Bobbin indications are inspected with Plus Point under the ARC, a more realistic definition of POPCD is obtained by replacing the "EOC-8 indications confirmed at EOC-9" category with "EOC-8 indications confirmed plus not inspected at EOC-9" indications. Table 6-1 shows the DCPP 2R8 results for both categories.

Table 6-2 shows a comparison of the DCPP Unit 2 EOC-8 POPCD based on the definition of "confirmed plus not inspected" indications with the EPRI Addendum 3 results. The DCPP Unit 2 POPCD is less than the Addendum 3 POPCD for bins less than 1.0 volts. For bins greater than 1.0 volts, the DCPP Unit 2 POPCD equals 1.0.

Table 6-2 shows that the DCPP data is slightly below the industry curves at voltages below 0.75 volts but is slightly above the industry curves above 1.0 volt. At voltages between 0.75 and 1.0 volts the results are close to that of the industry data. Because of the large number of new lower voltage indications, the DCPP data results in much smaller PODs at small voltages.

Use of the voltage-dependent POPCD is desirable to more accurately project voltage distributions for future outages. NEI letter dated September 22, 1999 requested NRC approval of the voltage-dependent POD, instead of the NRC POD of 0.6. As indicated in Section 4, the mandated POD of 0.6 was used in this analysis. It is noted that the mean POPCD for the DCPP Unit 2 data is about 0.61 (over the range of voltages where there was data, i.e., 0.1 to 1.6 volts), which is very close to the NRC mandated POD value of 0.6.

Table 6-3 shows a comparison of the DCPP Unit 2 BOC-10 DOS distribution from active tubes calculated with the NRC POD of 0.6, the EPRI Addendum-3 POPCD, and the DCPP EOC-8 POPCD. Note that the POPCD decreases the number of BOC-10 indications at higher voltages and increases the number of BOC-10 indications at lower voltages.

Table 6-1
DCPP Unit 2 EOC-8 Evaluation for Probability of Prior Cycle Detection
Composite of All Steam Generators

Voltage Bin	Indications Detected in 2R9 But Not Detected in 2R8 (i.e., New Indications)		Indications Detected in both 2R8 and 2R9		Indications Detected in 2R8	POPCD			
						Plus Point Confirmed		Plus Point Confirmed & Not Insp.	
	Plus Point Confirmed	Plus Point Confirmed + Not Insp.	Plus Point Confirmed	Plus Point Confirmed + Not Insp.	Plus Point Confirmed and Plugged	Frac.	Count	Frac.	Count
0.2	11	70	2	12	2	0.267	4 / 15	0.167	14 / 84
0.4	12	128	2	67	3	0.294	5 / 17	0.354	70 / 198
0.6	2	46	1	50	0	0.333	1 / 3	0.521	50 / 96
0.8	2	19	2	24	0	0.500	2 / 4	0.558	24 / 43
1	1	2	0	10	0	0.000	0 / 1	0.833	10 / 12
1.2	0	0	0	1	2	1.000	2 / 2	1.000	3 / 3
1.6	0	0	2	2	1	1.000	3 / 3	1.000	3 / 3
2	0	0	0	0	0		0 / 0		0 / 0
2.5	0	0	0	0	0		0 / 0		0 / 0
3.2	0	0	0	0	0		0 / 0		0 / 0
3.5	0	0	0	0	0		0 / 0		0 / 0
Total	28	265	9	166	8				

Table 6-2
DCPP Unit 2 EOC-8 Comparison with EPRI POPCD

Voltage Bin	Addendum-3 Updated	DCPP 2R8 (EOC-8)
0.1	0.21	0.125
0.2	0.34	0.171
0.3	0.47	0.333
0.4	0.56	0.374
0.5	0.65	0.545
0.6	0.70	0.467
0.7	0.76	0.571
0.8	0.80	0.533
0.9	0.83	0.778
1	0.85	1.000
1.2	0.89	1.000
1.4	0.90	1.000
1.6	0.91	1.000
1.8	0.92	-
2	0.93	-
3	0.98	-
3.5	1.00	-

Table 6-3
Comparison of DCPP Unit 2 BOC-10 Calculated Distribution of Indications Using NRC POD, EPRI Addendum 3 POPCD, and DCPP 2R8 POPCD

Voltage Bin	As-found EOC-9	BOC-10 w/POD of 0.6	BOC-10 w/EPRI Adden-3	BOC-10 w/DCPP2R8 POPCD
0	0	0.00	0.00	0.00
0.1	0	0.00	0.00	0.00
0.2	19	31.67	55.88	111.08
0.3	69	115.00	146.81	207.00
0.4	94	156.67	167.86	251.51
0.5	87	145.00	133.85	159.50
0.6	67	111.67	95.71	143.57
0.7	50	83.33	65.79	87.50
0.8	26	43.33	32.50	48.75
0.9	23	38.33	27.71	29.57
1	12	20.00	14.12	12.00
1.2	11	18.33	12.36	11.00
1.4	13	21.67	14.44	13.00
1.6	2	3.33	2.20	2.00
1.8	3	5.00	3.26	3.00
2	2	3.33	2.15	2.00
3	0	0.00	0.00	0.00
3.5	0	0.00	0.00	0.00
Total	478	796.67	774.64	1081.48

7.0 Tube Integrity Method and Evaluations

The Monte Carlo analyses used to calculate the SLB leak rates and tube burst probabilities for the projected EOC-10 voltage distributions are consistent with the methods used in Ref. 6. The FTI simulation analysis methodology is described in Refs. 4 and 5. In general, the methodology involves application of statistical correlations for burst pressure, probability of leakage and leak rate to a measured or calculated EOC distribution to estimate the likelihood of tube burst and primary-to-secondary leakage during a postulated SLB event. The Monte Carlo analyses account for correlation parameter uncertainties associated with burst pressure, leak rate probability, and leak rate, which are explicitly included by the sampling process. NDE and material property uncertainties are also similarly included.

This section presents the results of analyses carried out to predict leak rates and tube burst probabilities for postulated SLB conditions for the projected EOC-10 voltage distributions. Since SG 2-4 has the largest total number of indications and the largest number of indications over 1 volt, SG 2-4 was expected to yield the limiting SLB leak rates and burst probabilities for Cycle 10.

7.1 Leak Rate and Tube Burst Probability for EOC-10

Calculations to predict SLB leak rate and tube burst probability for each steam generator in DCPP Unit-2 at the EOC-10 conditions were carried out using the NRC-required constant POD value of 0.6 and the combination of a composite and/or generator-specific growth rate distributions for active tubes and a very conservative limiting growth rate distribution for deplugged tubes. The leak and burst results for each steam generator are given in Table 7-1.

The limiting EOC-10 SLB leak rate, 1.2448 gpm (room temperature), was predicted for SG 2-4. This generator had the largest number of indications as well as the largest number of deplugged tube indications being returned to service for Cycle 10 operation. This limiting leak rate value is about one order of magnitude below the allowable SLB leakage limit of 12.8 gpm. It should be noted that this overall plant limit has not been adjusted for leakage contributions from other ARCs that have been implemented during U2R9.

The limiting tube burst probability, 3.24×10^{-4}, was predicted for SG 2-4. It is two orders of magnitude below the NRC reporting guideline of 10^{-2}.

7.2 Summary and Conclusions

The requirements for burst probabilities are met at EOC-10 with no steam generator exceeding the $1x10^{-2}$ criteria. For the leak rate, the plant-specific value of 12.8 gpm (at room temperature) for the faulted steam generator was not exceeded for any steam generator.

Table 7-1
DCPP Unit 2 October 1999 Outage (2R9)
Summary of Calculations of Tube Leak Rate and Burst Probability at EOC-10 for 1 million Simulations

Steam Generator	POD Applied	Number of Indications at EOC-10 [1]	Probability of Burst		SLB Leak Rate [3,5] (gpm)
			Best Estimate[2]	95% UCL [4] (1 or More Failures)	
2-1	0.6	174.33	5.300×10^{-5}	6.663×10^{-5}	0.2349
2-2	0.6	98.67	3.300×10^{-5}	4.412×10^{-5}	0.1267
2-3	0.6	90.67	4.300×10^{-5}	5.545×10^{-5}	0.1500
2-4	0.6	497.00	2.940×10^{-4}	3.238×10^{-4}	1.2448
Acceptance Criteria				1.0×10^{-2}	12.8[6]

Notes:
(1) Adjusted for POD.
(2) Best Estimate is the number of trials with a failure divided by the number of trials.
(3) Equivalent volumetric rate at room temperature.
(4) The 95% Upper Confidence Limit (UCL) is based on the number of trials with one or more failures.
(5) The calculated total leak rate reflects the upper 95% quantile value at an upper 95% confidence bound.
(6) This limit has not been adjusted for leakage contributions from other ARCs that have been implemented during U2R9.

8.0 References

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