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PG&E Letter DCL-03-121

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Docket No. 50-323, OL-DPR-82
Diablo Canyon Unit 2
PG&E Response to NRC Questions on 2R11 Steam Generator Tube Inspections

Dear Commissioners and Staff:

Pacific Gas & Electric (PG&E) submitted Diablo Canyon Letter (DCL) DCL-03-076, dated June 23, 2003, providing the 90-day report of steam generator (SG) tube inspections performed during the 2003 Unit 2 eleventh refueling outage (2R11).

On August 8, 2003, a NRC staff e-mail requested additional information (RAI) regarding the 2R11 SG inspections. Enclosed is PG&E's response to the RAI.

If you have further questions please contact John Arhar at (805) 545-4629.

Sincerely

Lawrence F. Womack

ddm/469
Enclosure
cc/enc: Bruce S. Mallett
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State of California, Pressure Vessel Unit

A001

## PG&E Response to NRC Questions on Unit 2 Eleventh Refueling Outage Steam Generator Tube Inspection 90-Day Report

In PG&E Letter DCL-03-076 dated June 23, 2003, PG&E submitted to the NRC the Diablo Canyon Power Plant (DCPP) Unit 2 90-day report to document the steam generator (SG) tube condition monitoring (CM) and operational assessment (OA) following the Unit 2 eleventh refueling outage (2R11) SG tube inspections. On August 8, 2003, PG&E received an NRC request for additional information (RAI) on this report, specifically related to the outside diameter stress corrosion cracking (ODSCC) alternate repair criteria (ARC). This enclosure provides PG&E responses to the 10 NRC questions.

An additional NRC question was raised in a phone call with PG&E on September 26, 2003, and PG&E's response is included in this enclosure as PG&E Response to NRC Question No. 11.

### NRC Request for Additional Information

*"By letter dated June 23, 2003, Pacific Gas and Electric (PG&E) Company submitted a report summarizing the 2003 steam generator tube inspection results at Diablo Canyon Power Plant Unit 2.*

*In the submittal, two significant changes were proposed to the methodology for projecting the end-of-cycle (EOC) voltage distributions based on your assessments of the predictive methodologies outlined in Generic Letter (GL) 95-05. These changes include the use of a voltage-dependent growth rate (instead of the voltage independent growth rate) and the use of a voltage dependent probability of detection (POD) function termed the probability of prior cycle detection (instead of a constant POD of 0.6).*

*The purpose of the predictive methodologies outlined in GL 95-05 is to result in a conservative estimate of the EOC voltage distributions (which should then result in conservative projections of the probability of burst and accident induced leakage). For the staff to ascertain whether the methodology changes you propose will result in a conservative projection of the EOC voltage distribution, the methodology should be demonstrated to result in a conservative projection of the EOC voltage distribution for all cycles since the GL 95-05 repair criteria has been implemented.*

*Whereas a benchmarking study was provided in several recent submittals dated June 23, 2003 and June 26, 2003, these studies had several weaknesses including (1) it only focused on one cycle of operation, (2) the projections were not conservative in all cases, and (3) the assessment used data that was not available at the time the inspections were conducted (i.e., the composite probability of prior cycle detection (POPCD) included cycle 11* *data which was not available at the EOC 10). Given these weaknesses, the staff requests that a benchmarking analysis, which uses consistent assumptions from one cycle to the next, be provided for all cycles in which the voltage-based repair criteria were implemented at Diablo Canyon. The staff makes the following specific observations regarding the benchmarking study:"*

NRC Question No. 1:

*"With respect to the 21.5 volt indication, the staff has no objection to not including this indication in the growth rate distributions or the assessments since it is the staff's understanding that a separate methodology will be used to predict these extreme voltage indications."*

PG&E Response:

PG&E agrees that the 21.5 volt (V) indication should not be included in the benchmarking analyses. A separate methodology to predict extreme voltage indications is under development by EPRI. As such, an extreme voltage predictive method is not included in the benchmarking analyses.

NRC Question No. 2:

*"With respect to the POPCD evaluation, the POPCD function at each outage should only include data that was available at that time. A generic POPCD which includes data from other plants (at that time) may be used consistent with the methodology for determining when a generic POPCD curve should be used (versus a plant-specific POPCD)."*

PG&E Response:

As discussed with the NRC in the April 15, 2003, meeting, application of a plant-specific POPCD requires satisfaction of minimum data requirements for which preliminary guidelines are described below. If a plant does not meet the minimum data requirements, the industry POPCD distribution (ARC database Addenda POPCD) must be applied unless it is shown that the plant-specific POPCD distribution for ARC analyses yields a uniformly lower POD above 1.0 V and has a POD less than 0.35 at 0.1 V. The lower bound POD above 1.0 V assures a conservative plant-specific POD for significant ARC indications. The 0.35 value at 0.1 V represents an upper bound to existing POD distributions for axial ODSCC at tube support plate (TSP) intersections and assures a representative value for new undetected, low voltage indications.

A future EPRI ARC database Addendum (Addendum 6) is necessary to provide POPCD distributions developed from loglogistic fits to the data with uncertainties such as included in the DCPP-specific POPCD. Addendum 6 will also include the final industry recommendations on the minimum data requirements for a plant-specific POPCD. Preliminary guidelines for applying a plant-specific POPCD distribution, subject to industry review and update for inclusion in Addendum 6, are:

<u>Minimum Number of Inspections for Plant-specific POPCD Application</u>

A minimum of three consecutive inspections for a plant with one unit and a minimum of four inspections with at least two inspections in each unit for a plant with two units are required. If a two unit plant has the minimum of three consecutive inspections for one unit, that unit can apply a plant-specific POPCD.

<u>Minimum Total Number of Indications for Plant-specific POPCD Application</u>

The total number of indications must be at least 500 for a plant-specific application. This represents a very conservative population for defining a POD distribution when the data satisfies the higher voltage range requirement given below.

<u>Minimum Number of Detected and Rotating Pancake Coil Confirmed Indications in Upper Voltage Range</u>

The POPCD database must include a minimum of 20 detected and rotating pancake coil (RPC) confirmed indications above 1.0 V with at least 5 indications above 2.0 V for a plant with 3/4 inch tubing and a minimum of 20 detected and RPC confirmed indications above 2.0 V with at least 5 above 3.0 V for a plant with 7/8 inch tubing. The minimum of 20 indications is typical of a lower range for statistical acceptability to define a total POD distribution for reasonably distributed indications, and is typical of current EPRI examination technique specification sheet (ETSS) requirements. The requirement of at least 5 indications greater than 1 V above the GL 95-05 ARC repair limits assures detected indications near the voltage of about 3 V for which the POD is expected to be near unity. The minimum of 20 indications above the repair limit also shows that the ODSCC population has matured to repairable indications to support the POD development.

If the plant-specific POPCD satisfies the above preliminary minimum data requirements, there is no need to compare the plant-specific and industry POPCD distributions to select the more conservative distribution. The databases for POPCD would be much larger than generally applied to develop POD distributions (e.g., EPRI ETSS) with a representative sample of indications at least 2 V above the ARC repair limits.

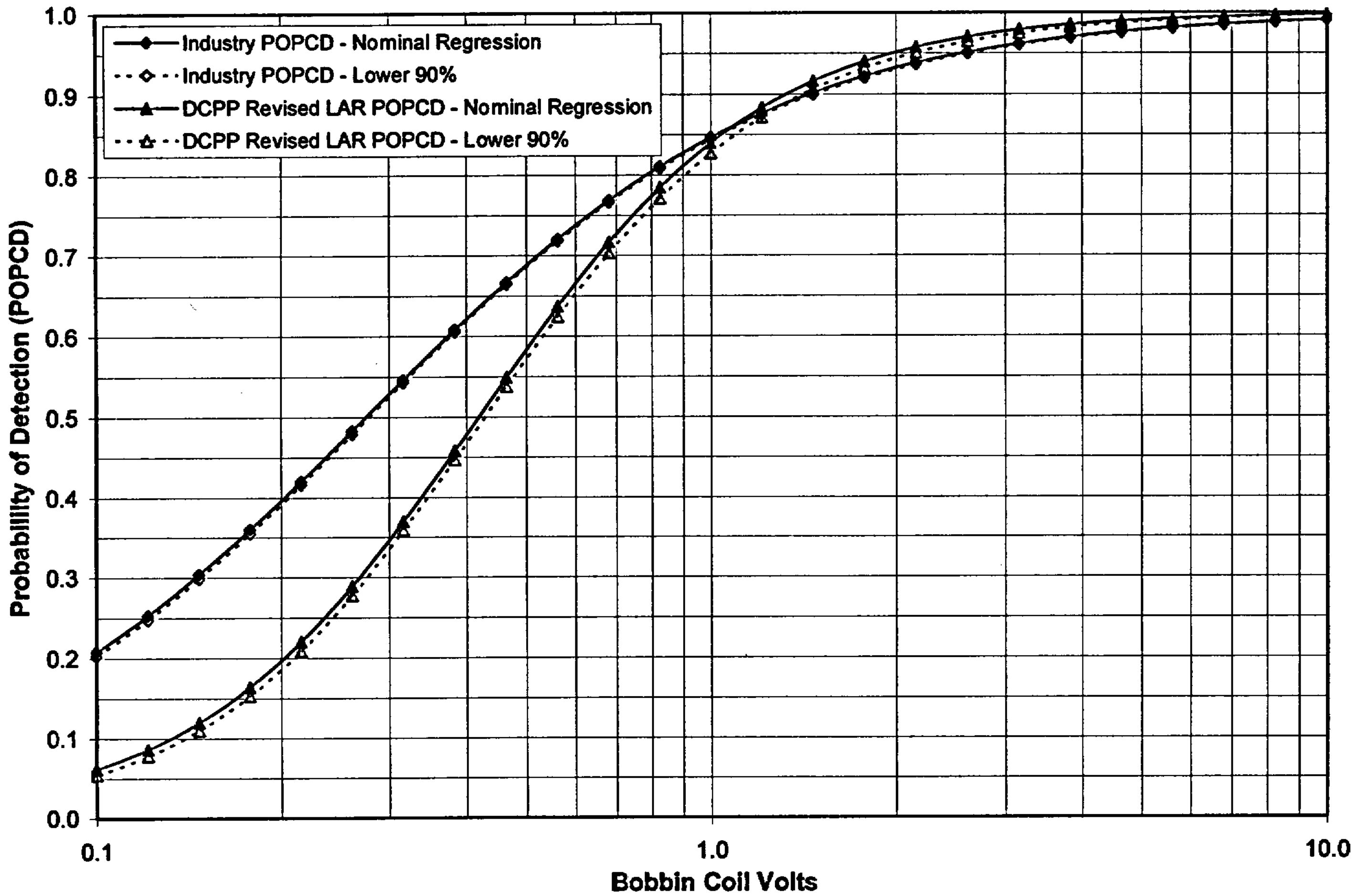
PG&E has reviewed these preliminary guidelines with respect to benchmarking applications in response to the NRC request. After the 2R11 inspections for DCPP Units 1 and 2 the three minimum data requirement criteria are satisfied, and, therefore, have an adequate database to define a plant-specific POPCD for Unit 2 Cycle 12. However, for prior cycle benchmarking, DCPP Units 1 and 2 do not satisfy all three minimum data requirement criteria, mainly due to not satisfying the third criteria regarding a minimum of 20 detected and RPC confirmed indications above 2.0 V. As shown in Figure 2-1, which compares the industry POPCD with the DCPP-specific POPCD (revised POPCD from Figure 1 of PG&E Letter DCL-03-109, "Supplemental Information to Support License Amendment Request 03-10, 'Revised Steam Generator Voltage-Based Repair Criteria Probability of Detection Method for Diablo Canyon Unit 2 Cycle 12,'" dated September 3, 2003), the DCPP-specific POPCD yields a POD less than 0.35 at 0.1 V, but yields a uniformly higher POD above 1.0 V. As a result, the industry POPCD must be used for prior cycle benchmarking. Below, Table 2-1 provides the industry POPCD correlations utilized in the benchmarking calculations. The industry POPCD curve is from Table 1 of PG&E Letter No. DCL-03-078, "License Amendment Request 03-10, 'Revised Steam Generator Voltage-Based Repair Criteria Probability of Detection Method for Diablo Canyon Unit 2 Cycle 12,'" dated June 26, 2003.

**Table 2-1**

| GLM Fit Analysis Results for Industry POPCD | |
|---|---|
| | **LogLogistic** |
| # of Data | 72407 |
| a.0 | 1.708744 |
| a.1 | 3.046718 |
| V11 | 0.000232 |
| V12 | 0.000458 |
| V22 | 0.001302 |
| Deviance | 83313.27 |
| MSE | 0.196237 |
| Binary | TRUE |
| Chi Sqr | 14208.6 |
| DoF | 72405 |
| p-Value | <2.9E-07 |

**Figure 2-1**

**Comparison of DCPP Revised LAR and Industry Loglogistic POPCD**



NRC Question No. 3:

*"With respect to the voltage dependent growth distribution, the staff notes that for the cycle 12 operational assessment, the middle voltage growth bin was increased by 10% during this assessment. Similar adjustments to the data for each cycle should be considered in this assessment if the data supports such an increase. In addition, the method by which this value is determined should be discussed. This adjustment was based, in part, on a comparison of Figures 3-22 and Figures 3-28. Please combine these two figures on one graph since the staff could not readily discern the 10% increase in this bin versus increases in other bins. Additional justification for increasing the middle bin by 10% was based on the data plotted in Figure 3-29. Please provide a similar assessment with the voltage growth data divided into voltage bins since Figure 3-29 shows an increase of 10% in growth for all indications (i.e., address whether the increase in growth in the middle bin is consistent with the overall increase in voltage growth)."*

PG&E Response:

As requested, Figure 3-1 below combines Figures 3-22 and 3-28, and provides the Cycles 10 and 11 voltage dependent growth (VDG) data divided into the Cycle 11 Bins (0-0.59, 0.59-1.66, >1.66 volts per effective full power years (V/EFPY)) on a single graph. Also included is the Cycle 9 data for Bins 1 and 2 for comparison as well (No Bin 3 data was present in Cycle 9). Table 3-1 depicts the average Bin 2 growth rates for each SG for Cycles 9, 10, and 11, as well as the average of all four SGs, using the Cycle 11 VDG breakpoints. The increase in average growth rate for all SGs in Bin 2 was 19 percent from Cycles 9 to 10 and 21 percent from Cycles 10 to 11. From Figure 3-1, it is seen that the cumulative distributions for Bin 2 (and Bin 1) remain relatively constant with minor oscillations in either direction over the last three cycles, but do not indicate a consistently increasing growth rate. Below about 0.9 cumulative probability distribution function (CPDF), Cycle 9 Bin 2 growth is comparable to Cycle 11 and larger than Cycle 10. Only 64 data points were present in Cycle 9, compared to 216 data points in Cycle 10 and 420 in Cycle 11. The Cycle 11 data is, therefore, considered a more mature population than Cycle 10, and as such is more representative of the VDG that is occurring to Bin 2 indications. As the population continues to mature, the Bin 2 growth curve will continue to shift towards the left on the CPDF curve (as additional slower growing data points are added) and then maintain relative consistency from cycle to cycle. The VDG data from European SGs that was presented to the NRC staff during the March 4, 2003 meeting supports the mature growth phenomenon of a large population of indications. Even though the Bin 2 data from Cycle 11 suggests a similarly mature population and the Bin 2 growth rate is not expected to significantly increase or decrease over Cycle 12, the Cycle 12 OA used a 10 percent increase to the Cycle 11 Bin 2 growth data.

In terms of the increase in average growth over the entire population as depicted in Figure 3-29 of the 90-day report, the actual increase from Cycle 10 to Cycle 11 was 13 percent. As discussed above, the 10 percent value was deemed as a conservative adjustment to an already representative population of indications that resided in Bin 2 at beginning of cycle (BOC) 11.

Results of Benchmarking Evaluation Relative to VDG (Delta Volts VDG Strategy)

In order to answer the main question of this RAI, benchmarking calculations were performed for Cycles 9 (voltage-based ARC was first implemented in Unit 2 refueling outage eight (2R8), through 2R11. Table 3-2 provides the results of the analyses, as well as the assumptions that were used for each analysis. As explained in response to NRC Question No. 2 above, the industry POPCD was utilized in all calculations. The Addendum 5 database, plus DCPP 2R11 pulled tube specimen data, correlations were used (all available industry data through September 2003), and 500,000 trials were run for all simulations. In keeping with the intent of the NRC's request to "use only data that was available at the time," a delta volts VDG strategy was derived and applied at each cycle in an effort to improve projections using only the current and previous inspection growth rate data. A discussion of this strategy is provided below.

For the EOC 9 projections, the first cycle of implementation of the voltage-based ARC at Unit 2, the amount of voltage growth data from Cycle 8 was limited. The growth rate used in these benchmarks was the same as that used in the 2R8 90-day report (an industry bounding curve was used because 200 DCPP Unit 2 growth data points were not yet available). As shown in Table 3-2, the EOC-9 projected probability of burst (POB) values for all SGs were conservatively over-predicted. The EOC-9 projected leak rate values for 2 SGs were slightly under-predicted (much less than 10 percent of the reporting threshold). However, the actual Cycle 9 growth rate data indicated a shift towards voltage dependency since a break point was present in the data at 0.42 V. To further assess the onset of VDG, the Cycle 8 data was binned in the same manner (using a 0.42 V breakpoint) and the two bins of data were compared to Cycle 9 bins. A 0.17 V/EFPY average growth rate increase was noted to exist in the >0.42 V bin. Therefore this difference was added to each growth point in Cycle 9 that was >0.42 V, prior to utilizing it for Cycle 10 projections. It is judged that adding an incremental voltage increase (delta volts) is more appropriate for growth adjustments than a percentage change to the growth distribution.

The EOC-10 projections using the delta volts VDG strategy defined above are shown in Table 3-2. In worst case SG 2-4, the EOC-10 projected POB was under-predicted by greater than 10 percent of the reporting threshold, even with the Cycle 9 adjustment. The Cycle 10 growth data, once analyzed, revealed an additional breakpoint in the voltage dependent growth (0.69v and 1.17v), thus accounting for the SG 2-4 POB under-prediction using the average adjustment from Cycle 9. However, significant margin still existed relative to the 1E-02 GL 95-05 reporting threshold, due to the small population of indications (493) detected. The shift to higher than predicted voltage dependent growth in Cycle 10 in SG 2-4 is not unexpected based on the small number of indications that were available at EOC-9 on which to base future predictions. However, after the population evolves into a mature and statistically significant data set, the EOC conditions would not be expected to be under-predicted in this manner. Based on this shift and the under prediction a methods evaluation is warranted for Cycle 11.

Therefore, for the EOC 11 projections, the delta volts VDG strategy was again applied. The Cycle 10 VDG breakpoints (0.69 V and 1.17 V) were applied to the Cycle 9 growth data. Comparison of the Cycle 9 and 10 bins identified a small decrease in the average growth of the lower and middle bins, but a significant increase in the upper bin average growth rate. The Cycle 9 upper bin contained 4 data points with an average growth of 0.274 V/EFPY, and the Cycle 10 upper bin contained 37 data points with an average growth rate of 0.725 V/EFPY. Therefore, assuming that a similar increase in growth would be present in Cycle 11 in the upper bin, a 0.451 V/EFPY adjustment was made for Cycle 10 growth in the upper bin. As shown in Table 3-2, the resulting POB and leak rate at EOC-11 using the adjusted Cycle 10 growth resulted in conservative POB and leak rate over-predictions in worst case SG 2-4. There were slight POB under-predictions in 2 SGs but much less than 10 percent of the reporting threshold. Evaluation of the Cycle 11 growth rate data revealed another shift in the break points. Therefore, since a growth adjustment was needed to obtain the SG 2-4 POB over-predictions, and due to the changes in the growth rate from Cycle 10 to 11, it is judged that EOC-12 projections needed to account for additional increases in growth in order to meet the intent of GL 95-05 guidance for using conservative growth rates in the OA.

As a result, the projected Cycle 12 growth was reassessed using the delta volts VDG strategy. The VDG breakpoints shifted in the Cycle 11 data to 0.61 V and 1.66 V compared to 0.69 V and 1.17 V in Cycle 10, indicating that voltage dependent growth rate changes were occurring in Cycle 11. The VDG analysis performed in Attachment 2 of Enclosure 4 of the 90-day report concluded that when combining the Cycle 10 and 11 data, the breakpoints were 0.59 V and 1.66 V, comparable to Cycle 11, but more statistically valid due to the larger number of data points. Therefore, for the Cycle 12 assessment using the delta volt strategy, the 0.59 V and 1.66 V break points were applied to the Cycles 10 and 11 growth data to assess the change in average growth in each of the VDG bins. (Note: The previous analyses in Enclosure 4 of the 90-day report used a 10 percent increase for Cycle 12 in the middle bin). It was observed that the average growth in the lower bin did not increase and the middle and upper bins had slight average growth increases of 0.06 and 0.08 V/EFPY, respectively. The resulting EOC-12 POB for the limiting SG 2-4 was recalculated using the DCPP-specific POPCD ("NRC POPCD") and the growth rate distribution in Table 3-12 of Enclosure 4 of the 90-day report, but replacing the 10 percent middle bin increase with the 0.06 V/EFPY increase and adding a 0.08 V/EFPY increase in the upper bin. The resulting EOC-12 POB is 5.94E-03, compared to the POB of 6.01E-03 from Table 4 of the September 3, 2003, supplement, which applied only the 10 percent increase to the middle bin. Therefore, based on the results of these benchmarks, which show negligible change in POB, the POPCD and VDG approach documented in the 2R11 90-day report provides conservative estimates for the EOC-12 conditions. However, as previously noted, it is more appropriate to account for adjustments in growth from cycle to cycle using a delta volts approach to each VDG Bin.

**Table 3-1**

**Summary of Bin 2 Growth Comparison**
**(Based on Cycle 11 breakpoints of 0.59 V and 1.66 V)**

| | SG 2-1 | SG 2-2 | SG 2-3 | SG 2-4 | Average | % Increase |
|---|---|---|---|---|---|---|
| Cycle 9 | -0.056 (14) | 0.166 (6) | 0.595 (5) | 0.310 (39) | 0.239 (64) | - |
| Cycle 10 | 0.218 (30) | 0.078 (24) | 0.245 (21) | 0.339 (141) | 0.284 (216) | 19 |
| Cycle 11 | 0.213 (67) | 0.162 (55) | 0.340 (41) | 0.417 (257) | 0.344 (420) | 21 |

Note: Growth is in terms of V/EFPY, the number of indications is in ().

## Table 3-2
## Benchmarking Results DCPP-2

| Cycle Designation | Steam Generator | Projected Results | | As-Found Results | | Growth Rate Used | | | POD Used (4) |
|---|---|---|---|---|---|---|---|---|---|
| | | POB | Leak Rate | POB | Leak Rate | # of Bins | Breakpoint(s) | Data Source | |
| EOC-9 | SG 2-1 | 2.36E-04 | 0.04 | 9.49E-06 | 0.01 | 1 | NA (3) | Industry Bounding | Industry |
| | SG 2-2 | 1.18E-04 | 0.02 | 3.89E-05 | 0.02 | 1 | NA (3) | Industry Bounding | Industry |
| | SG 2-3 | 6.75E-05 | 0.01 | 1.55E-05 | 0.02 | 1 | NA (3) | Industry Bounding | Industry |
| | SG 2-4 | 4.22E-04 | 0.12 | 5.58E-05 | 0.13 | 1 | NA (3) | Industry Bounding | Industry |
| EOC-10 | SG 2-1 | 5.34E-05 | 0.12 | 6.75E-05 | 0.10 | 2 | 0.42 | C9 Composite (1) | Industry |
| | SG 2-2 | 3.39E-05 | 0.06 | 1.26E-05 | 0.02 | 2 | 0.42 | C9 Composite (1) | Industry |
| | SG 2-3 | 7.22E-05 | 0.09 | 1.69E-04 | 0.14 | 2 | 0.42 | C9 Composite (1) | Industry |
| | SG 2-4 | 3.84E-04 | 0.77 | 1.94E-03 | 1.34 | 2 | 0.42 | SG24 C9 (1) | Industry |
| EOC-11 | SG 2-1 | 1.18E-03 | 0.70 | 1.22E-03 | 0.59 | 3 | 0.69/1.17 | C10 Composite (5) | Industry |
| | SG 2-2 | 4.26E-04 | 0.30 | 5.70E-04 | 0.31 | 3 | 0.69/1.17 | C10 Composite (5) | Industry |
| | SG 2-3 | 4.18E-04 | 0.28 | 1.58E-04 | 0.17 | 3 | 0.69/1.17 | C10 Composite (5) | Industry |
| | SG 2-4 | 5.42E-03 | 3.01 | 3.91E-03* | 2.62 | 3 | 0.69/1.17 | SG24 C10 (5) | Industry |

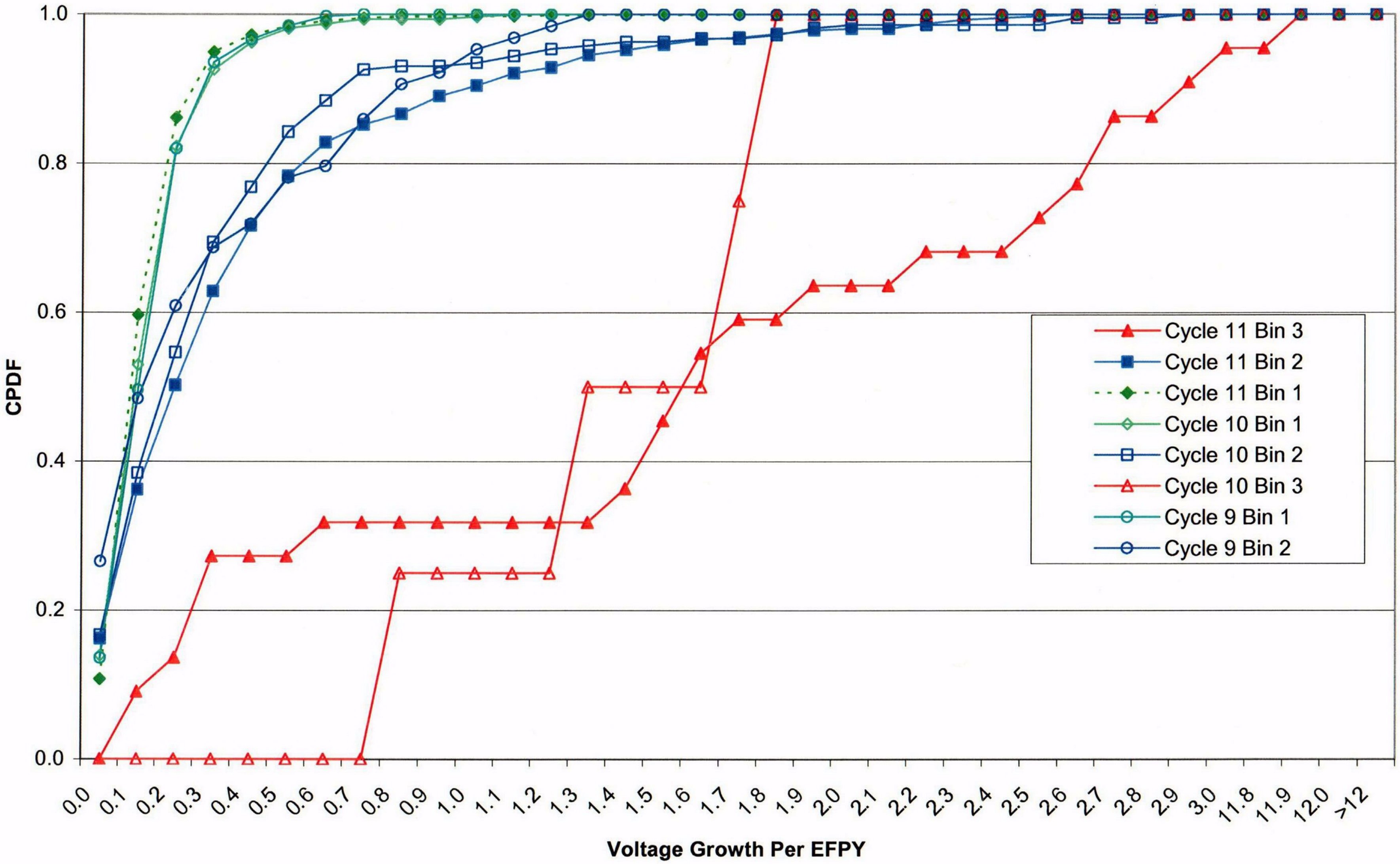
Notes:

1) Bin 2 growth was increased by 0.17v/EFPY based on comparison between Cycle 8 and Cycle 9 growth for indications >0.42 V at BOC.
2) All calculations used burst pressure, leak rate, and probability of leakage correlations that included the pulled tube results from DCPP 2R11.
3) The growth analysis of the Cycle 8 data showed no signs of voltage dependent growth. Therefore, a single independent growth distribution for all indications was used.
4) Per the proposed guidelines listed in Response to NRC Question No. 2, the industry POPCD was used for all of the benchmarking analyses.
5) Bin 3 growth adjusted 0.451 V/EFPY based on a comparison of Cycle 9 and Cycle 10 growth for indications >1.17 V at BOC.

* does not include R44C45 in as-found population, consistent with 90-day report.

**Figure 3-1**

**Voltage Dependent Growth Curves**
**DCPP2 All SGs Cycles 9, 10 and 11**
**(Based on Cycle 11 VDG Break points)**






C01

NRC Question No. 4:

*"The staff notes that the process of re-evaluating the data from the previous outage in determining the growth rate distribution result in the inclusion of many low growth rate indications. This reevaluation is an accepted practice; however, it may result in forcing voltage calls for eddy current signals which may not really represent the presence of a flaw resulting in a non-conservative growth rate distribution (since the frequency of the larger voltage growth rates is reduced). As a result, the growth rates for these indications may actually be higher (i.e., since the indications may have initiated during the course of the cycle rather than truly being present for the whole cycle). Your benchmark assessment should consider the effect of removing these indications from the growth rate distribution to determine if this re-evaluation process is resulting in non-conservative projections. An assessment of whether exclusion of this data affects the breakpoints in the VDG rate distribution should also be considered. The staff notes that you have observed that new indications are not exhibiting as much voltage dependent growth as repeat indications. Your assessment should address whether this could be a result of the above effect."*

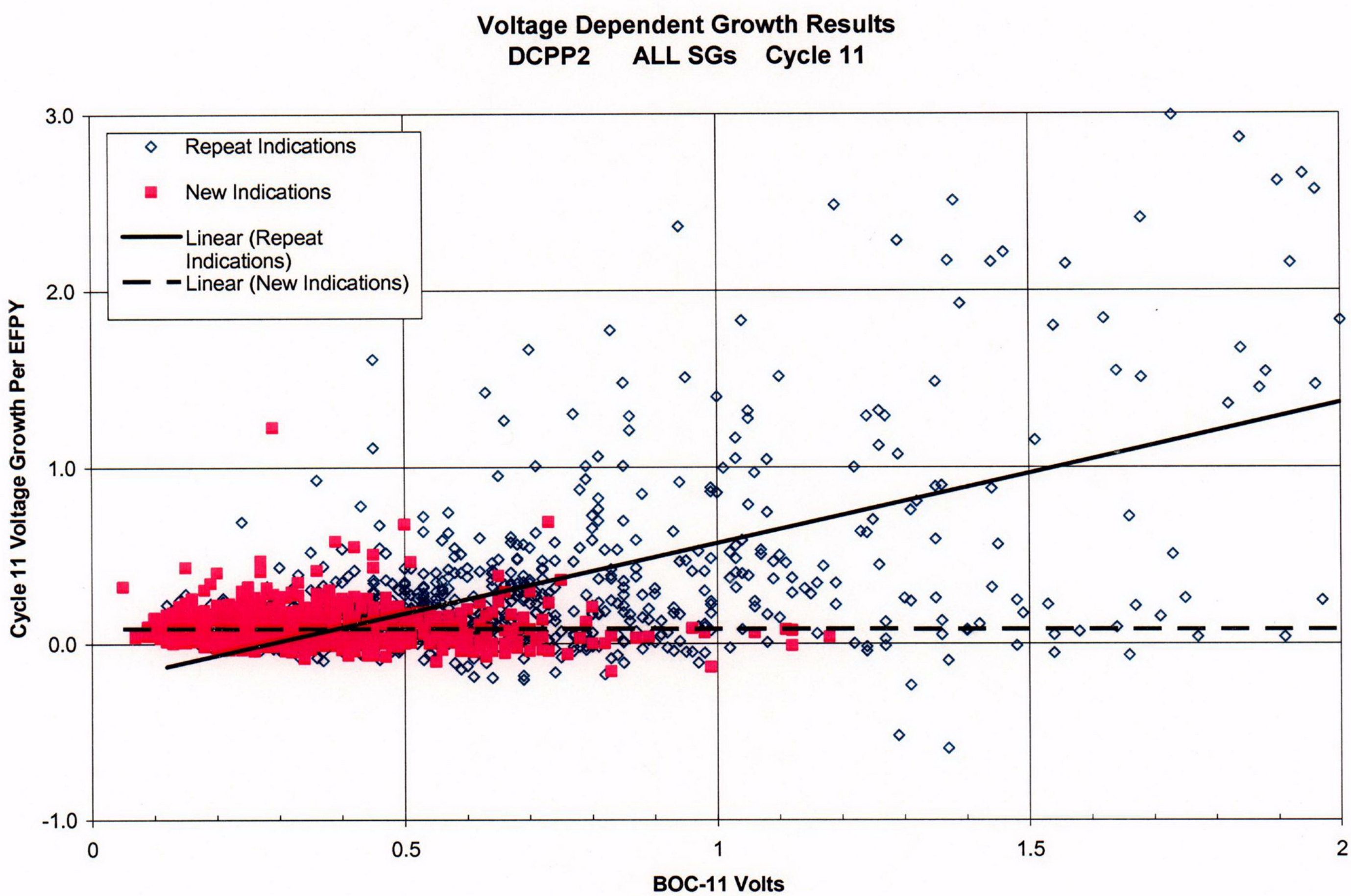
PG&E Response:

The practice of performing "lookups" for new distorted ODSCC signal (DOS) indications is performed in accordance with the requirements for evaluating TSP intersections with bobbin coil as defined in PG&E non-destructive examination Procedure, ET-7 "Eddy Current Examination of SG Tubing." There is no "forcing" of voltage calls on the previous data in order to obtain growth rate information. In fact, there were 11 DOS calls in 2R11 that were not present in the 2R10 data during the lookup. During the evaluation of the Cycle 11 growth rates, an assessment was made concluding that excluding these 11 indications would not affect the upper tail of the voltage growth distribution due to the low voltages at 2R11 (all $\leq$0.38 V). As such, these eleven indications are not included in the Cycle 11 growth evaluations and distributions.

The Cycle 11 growth data for all SGs (previously provided in Figures 3-10 to 3-13 of the 2R11 90-day report) is consolidated on a single graph in Figure 4-1 below, trending new and repeat indication voltage dependent growth rates. The figure clearly depicts that voltage dependent growth is primarily occurring in repeat indications. This is the expected condition due to the exponential dependence of volts on depth. The low voltages of the new indications suggest that they are shallow so the exponential effect on growth is minimal for them, compared to the higher voltage repeat indications that are likely deeper. In Figure 4-2 below, new and repeat cumulative growth curves were plotted along with the Cycle 11 voltage independent growth curve. This figure shows that the repeat indications do in fact grow faster than new indications. The graph also shows the independent curve does not bound the repeat growth, and as such, if the

Cycle 12 OA were to use an independent approach to growth, it would be nonconservative. However, for the Cycle 12 OA, a voltage dependent growth strategy is employed. Figure 4-3 provides the new and repeat indications plotted on a graph with the Cycle 11 VDG Bins growth curves for all indications, independent of new or repeat indications. This figure shows that the repeat indications are bounded by the upper and middle VDG growth curves. Since the curve for the new indications is closely represented by the Bin 1 VDG curve, a VDG analysis inherently accounts for new indications growing at a slower rate than repeat indications. Likewise, repeat indications being returned to service (and which start the cycle at a higher BOC voltage) are grown at either the Bin 2 or Bin 3 growth rates, which again bound the repeat indications growth when they are not "binned." Therefore, based on the currently proposed method for using VDG, it is not necessary to perform additional Cycle 12 OA projections or previous cycle benchmarks using new and repeat growth rates.

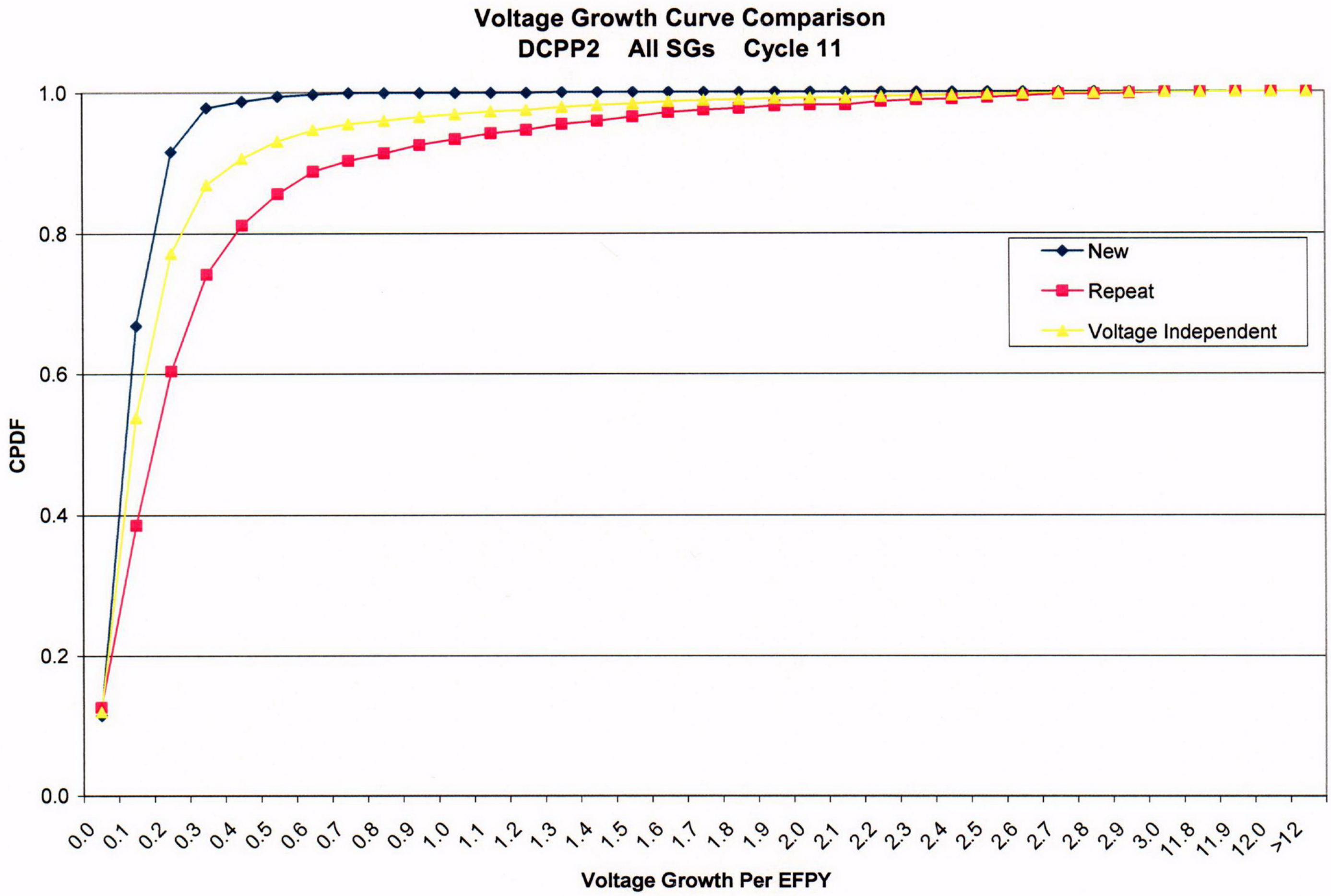
## Figure 4-1






EOZ

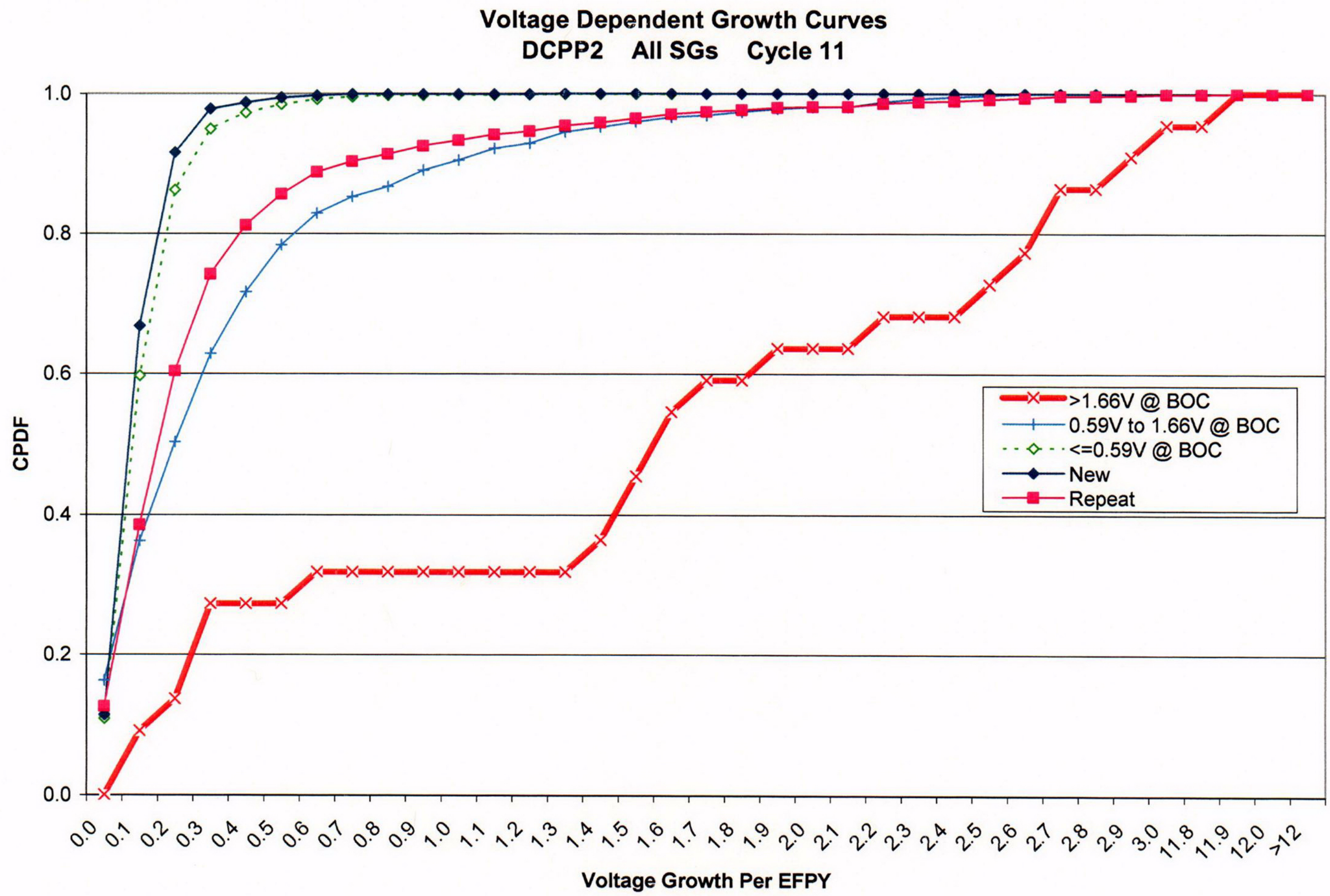
## Figure 4-2






C03

## Figure 4-3






C04

NRC Question No. 5:

*"With respect to the breakpoints in the VDG rate curves, discuss any physical insights of why the growth rates would change as a function of initial voltage amplitude (or more specifically what is occurring below 0.59 volts that is different from what is occurring between 0.59 and 1.66 volts). Discuss whether you have any insights of whether these breakpoints would change with time or would be well defined if a larger dataset were evaluated."*

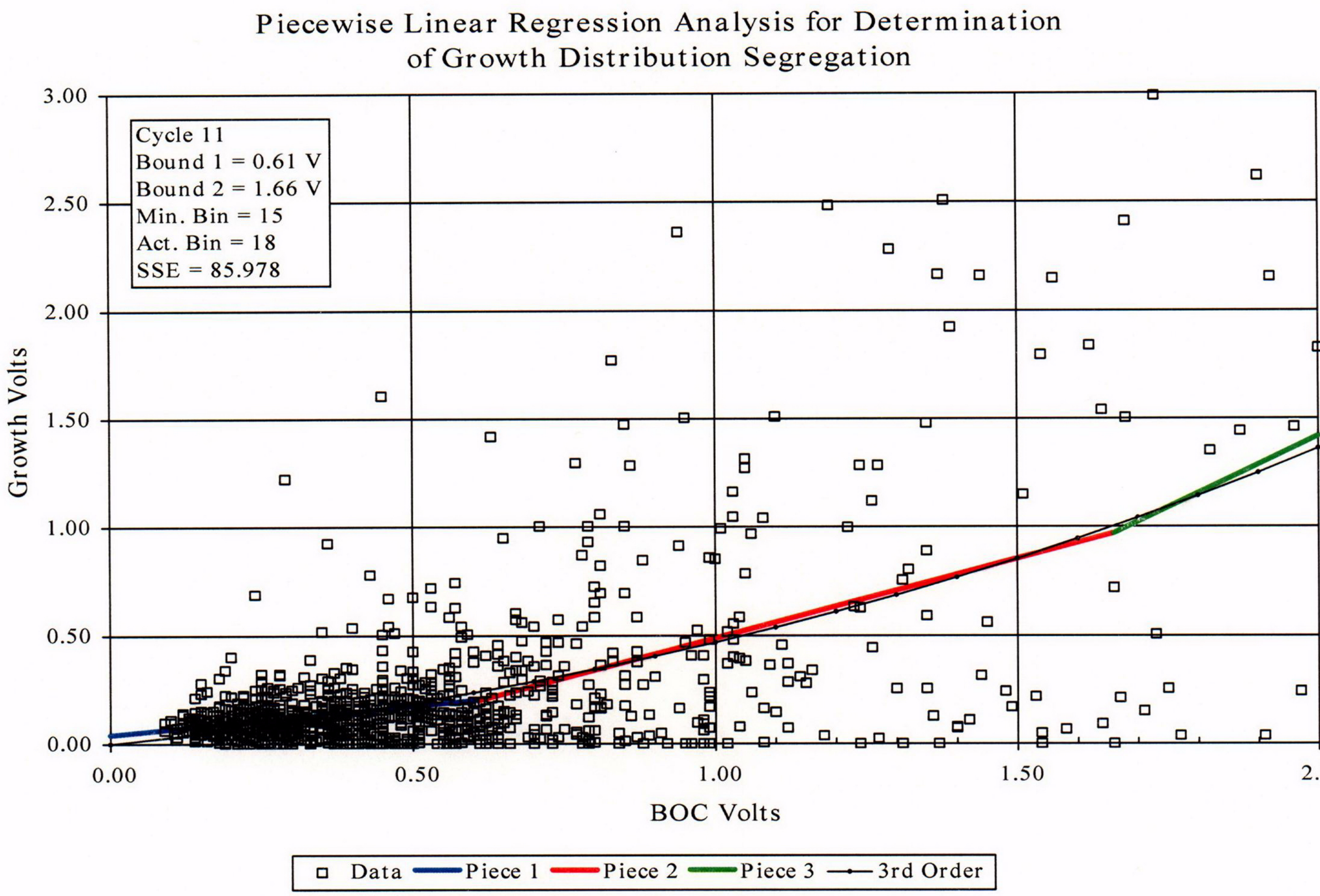
PG&E Response:

Bobbin coil voltage increases exponentially with depth and again exponentially with throughwall crack length. Consequently, for a given incremental growth in depth, the associated incremental increase in voltage will tend to increase exponentially with BOC depth and associated BOC volts. For low voltages, the exponential effect can be approximated as a linear effect and voltage growth is not a significant function of BOC volts. This concept is recognized in GL 95-05, which notes that an assessment is recommended to determine the voltage above which voltage growth becomes a significant function of BOC volts. Below about 0.59 V, ARC historical data have shown negligible VDG as also seen in the DCPP 2R11 data of Figure 5-1. Between about 0.59 V and 1.66 V, the DCPP growth data show a growth trend increasing with BOC volts, which reflects the deeper indications at the higher voltages. It can be reasonably expected that the VDG breakpoints will change moderately with time as the number of higher voltage indications increases. As more slow growing indications progress to higher voltages (population matures), it may be expected that the frequency of large growth rates in the VDG bins will decrease. This behavior is seen in European voltage growth data based on large populations of high voltage indications. The European data show incremental increases in growth with increases in BOC voltage, which tends to indicate that the VDG breakpoints become well defined with large datasets.

A piecewise linear fit to the data provides an advantage to a straight linear fit in that it provides an approximation to a polynomial or exponential relation. This can be seen by examining the comparison provided on Figure 5-1. In Figure 5-1 the distribution of growth as a function of initial voltage was fit to a third order polynomial in order to include the zero growth values in the regression. The dependence is not strong nonlinear. The index of determination, $R^2$, for a 1$^{st}$ order fit to the data is almost 31 percent while the value for a 3$^{rd}$ order polynomial is a little more than 32 percent. This indicates that the use of a polynomial does not result in a large increase in explaining the variance of the prediction by adding two orders of complexity to the model. However, it is apparent that accounting for the potential increase in the dependency by performing a trilinear fit is worthwhile in that predicted future indications will have larger amplitudes in greater proportion.

This observation also explains a comment made when the methodology was presented to the NRC staff at the meeting between PG&E and the NRC, in the NRC office on March 4, 2003. It was noted that the changes in the sum of squares of the error (SSE) were small in finding the best fit for the breakpoints. Since the data can be represented by a fairly smooth polynomial, the choice of breakpoints will not result in large changes to the SSE. This also means that there is nothing extraordinary about 0.59 V and 1.66 V, only that they represent the current best fit of a three part linear curve to a 3rd order polynomial. Since the polynomial description of the data is relatively smooth it would not be expected that there would be large changes in the locations of the breakpoints.

**Figure 5-1: Comparison of tri-linear fit of the growth data to a 3rd order polynomial fit**






C05

NRC Question No. 6:

*"It appears that the number of indications was underpredicted for several of the steam generators at the EOC 11. Consideration should be given for developing an approach which increases the number of indications to account for this phenomena. That is, if the initiation rate is increasing, some sort of an "acceleration" factor should be considered."*

PG&E Response:

Based on Table 6-11 of Enclosure 4 of the 90-day report, the total number of indications in SGs 2-2, 2-3, and 2-4 were underestimated by greater than 15 percent. The underestimates were largely limited to voltage bins less than 0.6 V. The cause of the low voltage underestimates cannot be conclusively determined, but could be attributed to several conditions, including: an increase in newly initiated indications, increased analyst sensitivity to calling low voltage indications, an overestimate of the low voltage POD, and an overestimate of the low voltage growth rate. An overestimate of the low voltage growth rate can lead to an overestimate of the number of indications >1 V.

A methods assessment was performed, which included a comparison of SG 2-4 EOC-11 projected population of indications versus the as-found conditions. These calculations were performed by first predicting the EOC-10 voltage distribution using the industry POPCD and Cycle 9 SG 2-4 VDG. Adjustments were then made to the BOC-11 voltage distribution by comparing the EOC-10 projection to the EOC-10 as-found results and adding indications to the appropriate bin ≤1 volt. The amount of increase was the difference between the projected and as-found population for that particular bin. The EOC-11 projection was then performed using the adjusted BOC-11 voltage distribution, Cycle 10 SG 2-4 VDG, and the industry POPCD. Table 6-1 provides these results. The column labeled 'Normal BOC Distribution' provides the results using the actual (unadjusted) BOC-11 distribution with Cycle 10 SG 2-4 VDG and industry POPCD, and is provided for comparison purposes only. The Cycle 10 growth did not include any adjustment factors based on NRC Question No. 3 responses.

As shown in Table 6-1, the number of indications at EOC-11 ≤1 volt using the adjusted BOC-11 distribution is still under predicted by about 14 percent, compared to the as-found conditions. However, the number of indications >1 volt is 26 percent over predicted when using this adjusted method, compared to 11 percent over predicted when using the normal method. A number of the indications added to the BOC distribution ≤1 volt were grown to >1 volt over the simulated cycle. This increase in population >1 volt is the principal contributor to the slight increases in burst probability and leakage at EOC-11. The increased population ≤1 volt has negligible influence on burst and leakage.

The DCPP-specific POPCD is lower than the industry POPCD in the low voltage bins. Therefore, another set of calculations was performed using the "DCPP New NRC POPCD" (Table 2 of DCL-03-109). These results are provided in Table 6-2. The results show that using the BOC adjustment method along with the DCPP-specific POPCD and SG 2-4 Cycle 10 VDG (no adjustments) provides a conservative projection of the number of indications $\leq$1 volt for SG 2-4 at EOC-11. For this case, the number of indications >1 volt is not increased as much as in the Table 6-1 results, thus reducing the effects of the BOC adjustment on burst and leakage compared to Table 6-1. The Table 6-2 calculations result in a larger projected population $\leq$1 volt compared to the as-found population, but also clearly show the negligible influence of these low voltage indications on burst and leakage.

As part of the methods assessment, EOC-12 projections for SG 2-4 were also performed. The number of SG 2-4 BOC-12 flaws was increased in each low voltage bin that had been underestimated at EOC-11. The amount of increase was the difference between the projected and as-found population for that particular bin at EOC-11. The adjusted BOC population was then subjected to the DCPP POPCD and Cycle 12 VDG using Monte Carlo techniques, and the resulting EOC-12 POB and leak rate was 6.31E-03 and 3.13 gpm, respectively (compared to the 6.01E-03 POB and 2.93 gpm leak rate from base case results in Table 4 of DCL-03-109). These represent negligible changes and demonstrate again the lack of effect that low voltage indications have on the tube integrity calculations.

In summary, accurately predicting the number of low voltage indications is not critical to projecting accurate EOC POB and leak rate results. More important to predicting accurate EOC integrity assessments is having an accurate growth rate to ensure that indications are grown to voltages that contribute to the tube integrity calculations. Refer to Tables 6-12 and 6-13 of Enclosure 4 of the 90-day report, which presented the results of EOC-11 predictions using DCPP POPCD and the actual Cycle 11 growth rates. These results further demonstrate these affects.

**Table 6-1**
**Benchmark of SG 2-4 EOC-11 Results Using Adjusted BOC Method and Industry POPCD**

| Voltage Category/ Result | EOC-11 Projected | | EOC-11 As-Found |
|---|---|---|---|
| | Normal BOC Distribution | Adjusted BOC Distribution | |
| ≤1 Volt Inds | 417.62 | 648.66 | 753 |
| >1 Volt Inds | 253.53 | 289.08 | 229 |
| >2 Volts Inds | 57.85 | 59.49 | 68 |
| >5 Volts Inds | 7.14 | 7.14 | 9 |
| Total Inds | 671.16 | 937.74 | 982 |
| Probability of Burst | 3.10E-03 | 3.18E-03 | 3.91E-03 * |
| Leak Rate (gpm) | 2.16 | 2.26 | 2.62 * |

* - Recalculated using Addendum 5 + DCPP pulled tubes correlations.

**Table 6-2**
**Benchmark of SG 2-4 EOC-11 Results Using Adjusted BOC Method and DCPP-Specific POPCD**

| Voltage Category/ Result | EOC-11 Projected | | EOC-11 As-Found |
|---|---|---|---|
| | Normal BOC Distribution | Adjusted BOC Distribution | |
| ≤1 Volt Inds | 617.22 | 804.03 | 753 |
| >1 Volt Inds | 272.74 | 282.15 | 229 |
| >2 Volts Inds | 57.82 | 58.39 | 68 |
| >5 Volts Inds | 6.89 | 6.90 | 9 |
| Total Inds | 889.97 | 1086.18 | 982 |
| Probability of Burst | 2.94E-03 | 2.95E-03 | 3.91E-03 * |
| Leak Rate (gpm) | 2.19 | 2.22 | 2.62 * |

* - Recalculated using Addendum 5 + DCPP pulled tubes correlations.

NRC Question No. 7:

*"The staff recognizes that from a safety perspective that differences between the condition monitoring (CM) or operational assessment (OA) are only significant when the limits are being approached (e.g., when the difference between the projections and the actual results are within 10% of the reporting threshold); however, to ensure that trends that may be indicative of a non-conservative methodology are promptly detected, a more appropriate measure for assessing the adequacy of a methodology may be when the projections and actual results differ by some specified value (e.g., 10%). Consideration should be given to this type of measure in your benchmarking analysis."*

PG&E Response:

Section 4.6 of the PG&E POPCD license amendment request (LAR) submittal (PG&E Letter DCL-03-078) describes the PG&E commitments for a specific methods assessment when the OA underestimates the CM results. The guideline on 10 percent of the burst and leak rate reporting threshold for OA underestimates is supplemented by the commitment to assess methods for smaller leak and burst values if the OA underestimates the CM results by an order of magnitude. Any OA underestimates will be discussed in the 90-day report but exceeding the threshold guidelines such as the 10 percent value would generally require methods sensitivity studies such as associated with POD and/or growth to identify any potential need for a methods revision. By this response, the LAR commitment on the guideline for SLB leak rate methods assessments is revised as follows: PG&E will perform a specific methods assessment when the OA SLB leak rate underestimates the CM results by either 0.5 gpm or an order of magnitude for small leak rates. That is, the 10 percent of the reporting threshold is revised to a 0.5 gpm value.

For burst, the 10 percent guideline would generally be applicable when the CM and OA values have a magnitude of about $10^{-3}$. When the burst values are smaller, a 10 percent difference between the CM and OA values, as suggested by the question, would be on the order of $10^{-4}$ or less. This magnitude for the difference is considered to be too small to require a methods assessment, as it is comparable to the difference that can sometimes be obtained by changing the starting random number in the Monte Carlo calculation. For Monte Carlo burst probability calculations on the order of $2\times10^{-4}$, burst probability variations up to $0.5\times10^{-4}$ have been found by changing the random seed in the Monte Carlo analyses.

For leak rates, the 10 percent guideline is replaced by a 0.5 gpm guideline for the differences between the CM values and the OA predictions. Differences of <0.5 gpm are not considered significant unless the differences approach the order of magnitude guideline. Differences on the order of a few tenths of a gpm are not considered significant for methods modification considerations as this difference can be obtained from moderate differences in the voltage distribution such as underestimates of the low voltage population below 1 volt due to the shallow slope of the leak rate correlation. Leakage calculations are less sensitive than burst to the Monte Carlo random seed with differences on the order of 0.02 gpm found for variations in the seed value.

The guidelines for requiring specific methods assessments in the POPCD LAR submittal (DCL-03-078), as modified for the 0.5 gpm leak rate guidline, are considered adequate to identify potential methods issues for differences between OA and CM analyses. More restrictive guidelines such as exceeding a 10 percent difference between the OA and CM results would be overly restrictive and unnecessarily conservative.

<u>NRC Question No. 8:</u>

*"With respect to the VDG rate distribution used for the cycle 12 OA, several indications from the prior cycle growth analysis (cycle 10) were included in the upper voltage bin. If inclusion of such data is needed to ultimately result in conservative projections of EOC conditions, a discussion of how and when to include such data should be provided. In addition, given that the growth rates increased from cycle 10 to cycle 11, discuss whether the growth rates for the cycle 10 data were increased by more than 10% (which was used to account for possible future "acceleration" in voltage growth rates). Also discuss, whether inclusion of this data resulted in more conservative results (i.e., does inclusion of this data result in lowering the frequency of observing the highest growth rates)."*

<u>PG&E Response:</u>

There were three data points that were added from the SG 2-4 Cycle 10 growth rate distribution to the projected growth distributions for each SG Cycle 12 OA. These points consisted of all of the upper bin data points in SG 2-4 Cycle 10, with no adjustment or increase (e.g., 10 percent). As stated in Enclosure 4 of the 90-day report (DCL-03-076), the Cycle 10 data points were in the 0.8, 1.7, and 1.8 V/EFPY bins in the growth file used in the Monte Carlo analysis. For reference, the Cycles 10 and 11 growth data in Bin 3 are provided in Table 8-1, segregated by cycle. The reason that the data points were added to the Cycle 11 data set was based on the results of the VDG bin analysis of the voltage growth versus BOC voltage, when Cycles 10 and 11 data from SG 2-4 data were combined. The VDG breakpoints from the Cycle 11 analysis were at 0.61 V and 1.66 V at BOC, and when combined and analyzed with Cycle 10 data, were 0.59 V and 1.66 V. Therefore the data sets were concluded to be related across all voltages (not just the upper bin) and that combining the data in the upper bin was acceptable for Cycle 12 OA predictions (Attachment 2 of Enclosure 4 of the 90-day report). There were five other Cycle 11 Bin 3 data points in the other SGs: 3 in SG 2-1 and 2 in SG 2-2. Only one of these data points was added to the SG 2-4 Cycle 12 Bin 3 growth because it was one of the three highest growth rates for Cycle 11 (2.9 V/EFPY). This point was added to increase conservatism in SG 2-4 Cycle 12 projections, since the point was in the higher ranges. Refer to Tables 3-10 and 3-12 of Enclosure 4 of the 90-day report for the specific data used in the Cycle 12 OA calculations.

Table 8-1 shows 26 total data points in Bin 3, 22 from Cycle 11 and 4 from Cycle 10. Of the Cycle 11 data points, 17 are from SG 2-4 and 5 are from the other 3 SGs. The SG 2-4 Cycle 12 OA had 21 data points: 17 from SG 2-4 Cycle 11, 1 from SG 2-1 Cycle 11 (the largest of the 5 from the other SGs), and 3 from SG 2-4 Cycle 10 (1 data point from SG 2-3 Cycle 10 was not added to any of the data because it was a lower growth rate value relative to the other data points). The other SGs Cycle 12 OA Bin 3 growth distribution had 22 data points: 17 from SG 2-4, plus all other remaining 5 Cycle 11 data points. Once again because of their voltage relative to the other 22 points, the Cycle 10 data points from SG 2-4 (3 points) and SG 2-3 (1 point) were not added to this data set for EOC-12 calculations. The effect of these data points on EOC-12 projections in SG 2-4 is provided below.

It is expected with time that the growth curve for Bin 3 (or any VDG bin) will continue to move to the left on a CPDF curve as more data points are added to it that represent the slower growing indications moving into that bin. The European data presented to the NRC in the meeting with PG&E on March 4, 2003, represents a mature population of indications that exhibit this behavior. Currently, the growth data for DCPP Unit 2 in Bin 3 for Cycles 10 and 11 (see Table 8-1) represents mostly the faster growing indications growing into this bin, since 18 of the 26 have a growth rate of >1.3 V/EFPY, and as such is considered conservative for Cycle 12 projections.

In order to demonstrate the affect of adding the three Cycle 10 indications into the Cycle 12 Bin 3 growth distribution, a new analysis was performed removing these data from the growth file. The resulting EOC-12 POB for SG 2-4 (the bounding SG) increased to $5.91 \times 10^{-3}$ (using the "LAR POPCD" from the 90-day report) compared to the $5.52 \times 10^{-3}$ result (documented in the 90-day report) when the three points were included in the calculation. The reason for the increase is due to the fact that the revised growth distribution contained three less points (18 instead of 21) than the original 90-day report analysis and therefore increased the chances of the Monte Carlo simulation picking the 11.9 V/EFPY growth point by about 16.8 percent.

Other assessments on the effect of the number of data points in Bin 3 were performed for the SG 2-4 Cycle 12 operational assessment. These assessments included the average Bin 2 and 3 adjustments discussed in the response to NRC Question No. 3 above, but removed the 11.9 V/EFPY growth point in accordance with the response to NRC Question No. 1. The results are tabulated below in Table 8-2 and show that once the 11.9 V growth point is removed from the Bin 3 data set, the number of remaining data points has an insignificant effect on the POB result at EOC-12. Also, the estimated POB at EOC-12 is much lower than when conservatively assuming that another large voltage growth will occur during Cycle 12 in SG 2-4.

Assuming that the current VDG analysis breakpoints are approximately the same for Cycle 12 actual growth, coupled with the fact that PG&E repaired indications at 1.2 V at 2R11, there will be no additional BOC voltage data points available from Unit 2 Cycle 12 operation for inclusion in the upper bin analysis. Also, based on the POPCD work performed to date for DCPP, there have been no "new" indications detected at $EOC_{n+1}$ that had a "look-up" voltage of >1.66 V at $EOC_n$, and this trend would continue to be expected. Therefore the dataset in the uppermost growth bin is not expected to increase for Cycle 13 OAs. For future analyses, it is expected than an industry method will be applied to account for a potential very large voltage growth to replace the 11 V/EFPY data point. The extreme voltage growth method would be independent of the plant-specific growth distribution in the VDG bins.

## Table 8-1

| Cycle 10 and 11 Bin 3 Growth Data (>1.66 BOC volts) | | |
|---|---|---|
| Voltage Growth/EFPY | Cycle 10 Number of Indications | Cycle 11 Number of Indications |
| 0.0 | 0 | 0 |
| 0.1 | 0 | 2 |
| 0.2 | 0 | 1 |
| 0.3 | 0 | 3 |
| 0.4 | 0 | 0 |
| 0.5 | 0 | 0 |
| 0.6 | 0 | 1 |
| 0.7 | 0 | 0 |
| 0.8 | 1 (Note 2) | 0 |
| 0.9 | 0 | 0 |
| 1.0 | 0 | 0 |
| 1.1 | 0 | 0 |
| 1.2 | 0 | 0 |
| 1.3 | 1 (Note 1) | 0 |
| 1.4 | 0 | 1 |
| 1.5 | 0 | 2 |
| 1.6 | 0 | 2 |
| 1.7 | 1 (Note 2) | 1 |
| 1.8 | 1 (Note 2) | 0 |
| 1.9 | 0 | 1 |
| 2.0 | 0 | 0 |
| 2.1 | 0 | 0 |
| 2.2 | 0 | 1 |
| 2.3 | 0 | 0 |
| 2.4 | 0 | 0 |
| 2.5 | 0 | 1 |
| 2.6 | 0 | 1 |
| 2.7 | 0 | 2 |
| 2.8 | 0 | 0 |
| 2.9 | 0 | 1 |
| 3.0 | 0 | 1 |
| 11.8 | 0 | 0 |
| 11.9 | 0 | 1 |
| 12.0 | 0 | 0 |
| >12 | 0 | 0 |
| TOTAL | 4 | 22 |

Note 1: SG 2-3 data point
Note 2: SG 2-4 data points.

**Table 8-2**
**Sensitivity Studies for Bin 3 Growth Rates in SG 2-4**
**w/o 11.9 V/EFPY Point**

| Growth Used | # of Data in Bin 3 | EOC-12 POB Result |
|---|---|---|
| Cycle 10+11 All SGs combined | 25 | 2.78 E-03 |
| Cycle 10+11 SG 2-4 and 1 point from Cycle 11 SG 2-1 | 20 | 2.73 E-03 |
| Cycle 11 SG 2-4 and 1 point from SG 2-1 combined | 17 | 2.76 E-03 |

NRC Question No. 9:

*"In assessing the conditional probability of burst and accident induced leakage associated with an EOC distribution (projected or actual), the use of one correlation (e.g., the most recent) would be acceptable for all analysis rather than using the correlations that were available at the time of the inspection. That is, regardless of the correlation used, the same one should be used in all analyses."*

PG&E Response:

The benchmarking in this submittal uses the same correlation for all analyses. The correlation is based on the EPRI ODSCC ARC Database, Addendum 5, and includes the recent DCPP tubes pulled in 2R11. Hence, the database is referred to as the "Addendum 5+ Database", and the correlation parameters are provided in Tables 5-3, 5-4, and 5-5 in Enclosure 4 of PG&E Letter DCL-03-076.

NRC Question No. 10:

*"Table 3-4 of Enclosure 4 to your June 23, 2003 letter, lists the largest voltage growth rates observed during cycle 11. All of these indications were single axial indications. Please discuss whether the growth rate distribution for single axial indications is different than that for multiple axial indications and whether separate growth rate distributions should be used for assessing these data sets. If so, please discuss whether additional rotating probe testing would need to be performed to determine which indications are single axial indications and which ones are multiple axial indications (or volumetric)."*

PG&E Response:

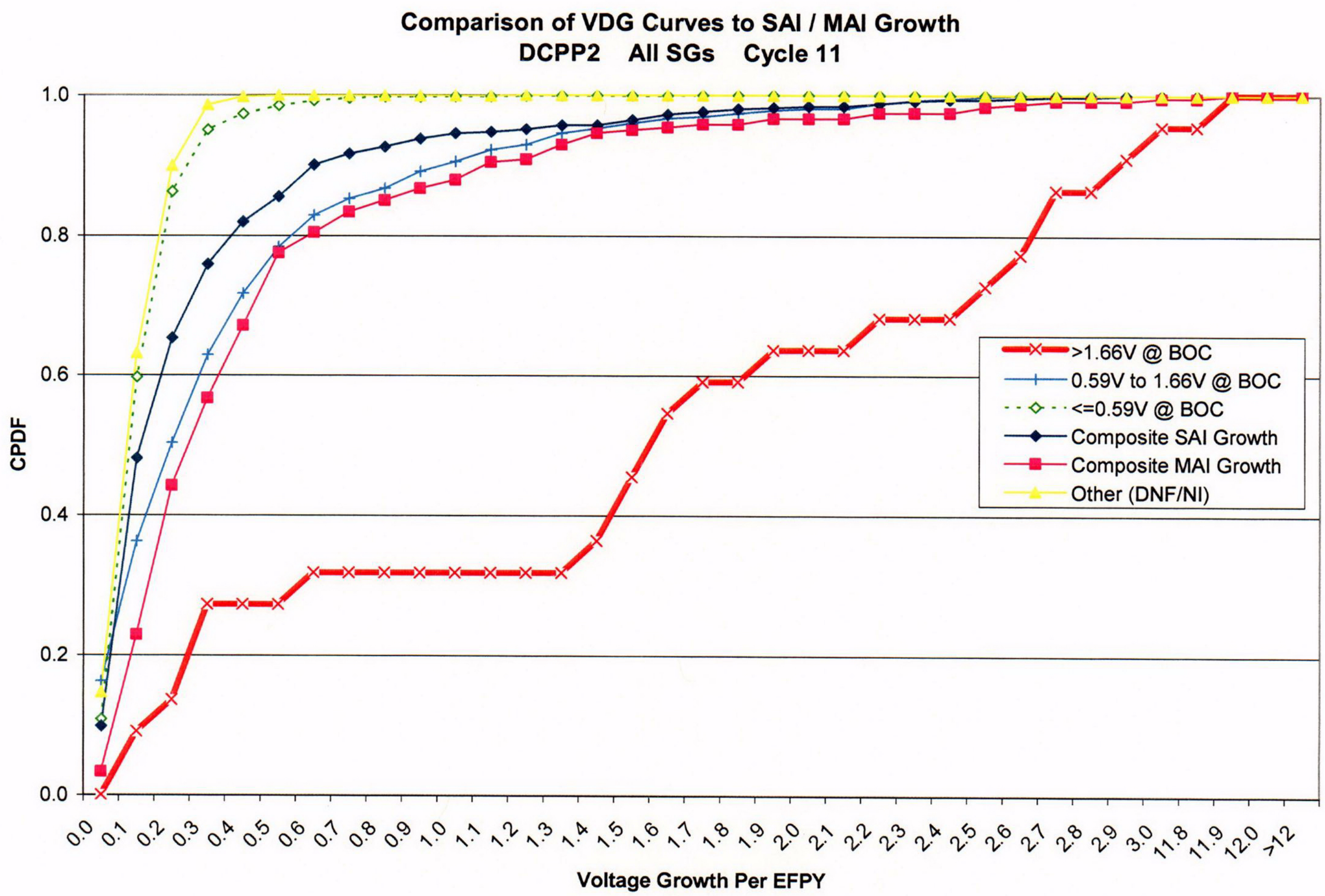
Table 3-4 of Enclosure 4 of the 90-day report (DCL-03-076) was constructed to show that the indications were indeed confirmed as axial ODSCC and the term single axial indication (SAI) is not intended to imply that all of these indications were single cracks. Many of these locations contained multiple cracks. The revised Table 3-4 is provided in Table 10-1 below and clarifies that the indications were a mixture of morphologies, consistent with the EPRI ODSCC Database flaw complement and industry experience.

The Cycle 11 growth rate data was segregated into categories for single and multiple confirmed axial indications. A total of 750 DOS were confirmed during the Plus Point inspections performed at 2R11 (240 multiple axial indications (MAIs) and 510 SAI). The remaining 1103 DOS were either not Plus Point inspected (NI) or did not confirm (DNF) by Plus Point as degradation. The voltage growth for these indications is depicted graphically in Figure 10-1 below. As expected, the voltage growth for the TSP intersections affected by MAIs is higher than that for intersections that are affected by SAIs. The reason for this affect is that the bobbin coil voltage is an "integral" of all the flaws present at the TSP, so a change in depth of any of the secondary flaws present or the development of an additional flaw during a cycle would have a higher resultant growth rate compared to a primary SAI growing only in depth during the cycle. The DNF/NI curve in Figure 10-1 contains the indications that were not Plus Point inspected or did not confirm with Plus Point. It is important to note that if more of these indications had been inspected with Plus Point, the result would have been to "pull" the SAI and MAI growth curves further to the left, since a large number (about 90 percent of 1103) of lower growth values would be added to those curves based on the overall DOS confirmation of about 90 percent. Therefore, additional Plus Point inspections are not warranted in an effort to determine which indications are SAIs and which ones are MAIs. Since the growth data show the expected trend that MAI growth is moderately larger than SAI growth and that the non-Plus Point inspected population could further reduce the differences, it is further concluded that there is no need to separate MAIs and SAIs in the growth distributions used for OA analyses.

## Table 10-1
## (Revised Table 3-4 of Enclosure 4 of 90-day Report)
### Summary of Largest Voltage Growth Rates per EFPY

| SG | Row | Col | Elev | Volts | Previous Volts (2R10) | Growth/ EFPY | Plus Pt Result | New? |
|---|---|---|---|---|---|---|---|---|
| 24 | 44 | 45 | 2H | 21.5 | 2 | 11.869 | 2 SAI | Repeat |
| 24 | 18 | 76 | 2H | 6.64 | 1.73 | 2.988 | 2 SAI | Repeat |
| 21 | 31 | 51 | 1H | 6.54 | 1.84 | 2.861 | 1 SAI | Repeat |
| 22 | 38 | 40 | 1H | 6.31 | 1.94 | 2.660 | 2 SAI | Repeat |
| 24 | 12 | 38 | 1H | 6.2 | 1.9 | 2.617 | 1 SAI | Repeat |
| 21 | 37 | 45 | 2H | 6.18 | 1.96 | 2.568 | 1 SAI | Repeat |
| 24 | 24 | 74 | 2H | 5.5 | 1.38 | 2.508 | 2 SAI | Repeat |
| 24 | 13 | 76 | 2H | 5.27 | 1.19 | 2.483 | 5 SAI | Repeat |
| 24 | 3 | 50 | 2H | 5.64 | 1.68 | 2.410 | 2 SAI | Repeat |
| 24 | 31 | 39 | 1H | 4.82 | 0.94 | 2.362 | 1 SAI | Repeat |
| 24 | 29 | 48 | 2H | 5.04 | 1.29 | 2.282 | 2 SAI | Repeat |
| 21 | 30 | 41 | 1H | 5.1 | 1.46 | 2.215 | 1 SAI | Repeat |
| 24 | 15 | 80 | 2H | 4.93 | 1.37 | 2.167 | 4 SAI | Repeat |
| 24 | 1 | 52 | 1H | 4.99 | 1.44 | 2.161 | 1 SAI | Repeat |
| 24 | 5 | 50 | 1H | 5.46 | 1.92 | 2.155 | 2 SAI | Repeat |
| 24 | 35 | 57 | 2H | 5.09 | 1.56 | 2.149 | 2 SAI | Repeat |
| 24 | 7 | 48 | 2H | 4.55 | 1.39 | 1.923 | 4 SAI | Repeat |
| 24 | 25 | 60 | 2H | 4.64 | 1.62 | 1.838 | 2 SAI | Repeat |
| 23 | 9 | 23 | 1H | 4.04 | 1.04 | 1.826 | 1 SAI | Repeat |
| 24 | 19 | 84 | 2H | 5 | 2 | 1.826 | 5 SAI | Repeat |

## Figure 10-1






C06

NRC Question 11:

*"Provide the EOC-12 Projections and POB and leak rate results of record for the method that PG&E has determined to be the most appropriate for predicting EOC-12 conditions."*

PG&E Response:

The EOC-12 projections that are considered the results of record for all SGs use the DCPP-specific POPCD (termed "New NRC POPCD" in Table 2 of DCL-03-109) and voltage dependent growth (with break points of 0.59 V and 1.66 V) with delta voltage increases applied to the middle and upper bins of 0.06 and 0.08 V/EFPY, respectively. Based on benchmarking studies provided in this enclosure, PG&E believes these methods are repeatable and provide conservative leak and burst estimates. The delta volts adjustment method is described in response to NRC Question No. 3.

Table 11-1 provides a summary of the delta volts bin growth comparison between Cycles 10 and 11, and provides the basis for the 0.06 and 0.08 V/EFPY adjustments applied in Cycle 12.

Table 11-2 provides the revised growth rate distributions used for the EOC-12 projections after each Bin 2 and Bin 3 data point was adjusted. Note that the resulting distribution results in minor changes to the original distributions used in the 90-day report which had used a 10 percent adjustment to the middle bin (refer to Table 3-12 of Enclosure 4 of the 90-day report (DCL-03-076)).

Table 11-3 provides the POPCD correlation used in Cycle 12 that corresponds to the POPCD data in Table 2 of DCL-03-109.

Table 11-4 provides the revised DCPP Unit 2 EOC-12 POB and steam line break (SLB) leak rate projections that supersede the values in the 90-day report. These values support full cycle operation of Unit 2 Cycle 12.

Table 11-5 provides the EOC-12 projected distributions that will be assessed against the as-found conditions at EOC-12. Figures 11-1 through 11-4 provide the EOC-12 distributions graphically.

In conclusion, PG&E has determined that acceptable conditions relative to axial ODSCC at TSPs will exist at Unit 2 EOC-12 relative to the GL 95-05 reporting thresholds for POB and leak rate and that the methods for prediction are conservative.

Table 11-1

| Bin Average Voltage and Delta Volts Increase from Cycle 10 to Cycle 11 (Based on Cycle 11 breakpoints of 0.59 V and 1.66 V) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cycle | SG 2-1 | SG 2-2 | SG 2-3 | SG 2-4 | Average | ΔV Increase |
| Bin 1 | 10 | 0.121 (137) | 0.084 (83) | 0.072 (74) | 0.129 (344) | 0.115 (638) | - |
| | 11 | 0.087 (277) | 0.069 (217) | 0.091 (215) | 0.127 (702) | 0.104 (1411) | -0.100 |
| Bin 2 | 10 | 0.218 (30) | 0.078 (24) | 0.245 (21) | 0.339 (141) | 0.284 (216) | - |
| | 11 | 0.213 (67) | 0.162 (55) | 0.340 (41) | 0.417 (257) | 0.344 (420) | +0.060 |
| Bin 3 | 10 | NA | NA | 1.299 (1) | 1.398 (3) | 1.373 (4) | - |
| | 11 | 2.321 (3) | 2.164 (2) | NA | 1.200 (16)<br>1.827 (17)* | 1.452 (21)<br>1.925 (22)* | +0.079** |

* - provided for information only and includes the 11.9 V/EFPY data point
** - excludes the 11.9 V/EFPY data point, since it is included in the actual growth rate for EOC-12 projections
() – is the number of data points

## Table 11-2: VDG Distributions Used for EOC-12 Monte Carlo Simulations

| Growth Distributions Used for SGs 2-1, 2-2, and 2-3 (All SGs combined) | | | |
|---|---|---|---|
| Growth in Volts/EFPY | BOC Voltage | | |
| | <=0.59V | 0.59V to 1.66V[1] | >1.66V[2] |
| 0 | 152 | 24 | 0 |
| 0.1 | 690 | 75 | 0 |
| 0.2 | 374 | 76 | 2 |
| 0.3 | 124 | 62 | 2 |
| 0.4 | 32 | 38 | 2 |
| 0.5 | 17 | 38 | 0 |
| 0.6 | 10 | 22 | 1 |
| 0.7 | 5 | 18 | 0 |
| 0.8 | 3 | 7 | 0 |
| 0.9 | 0 | 6 | 0 |
| 1 | 1 | 10 | 0 |
| 1.1 | 0 | 7 | 0 |
| 1.2 | 1 | 5 | 0 |
| 1.3 | 1 | 3 | 0 |
| 1.4 | 0 | 8 | 0 |
| 1.5 | 0 | 2 | 1 |
| 1.6 | 0 | 5 | 3 |
| 1.7 | 1 | 0 | 1 |
| 1.8 | 0 | 1 | 1 |
| 1.9 | 0 | 4 | 0 |
| 2 | 0 | 1 | 1 |
| 2.1 | 0 | 0 | 0 |
| 2.2 | 0 | 0 | 0 |
| 2.3 | 0 | 4 | 1 |
| 2.4 | 0 | 1 | 0 |
| 2.5 | 0 | 1 | 1 |
| 2.6 | 0 | 2 | 0 |
| 2.7 | 0 | 0 | 2 |
| 2.8 | 0 | 0 | 1 |
| 2.9 | 0 | 0 | 0 |
| 3 | 0 | 0 | 1 |
| 3.1 | 0 | 0 | 1 |
| 11.8 | 0 | 0 | 0 |
| 11.9 | 0 | 0 | 0 |
| 12 | 0 | 0 | 1 |
| >12 | 0 | 0 | 0 |
| **Total** | **1411** | **420** | **22** |

| Growth Distributions Used for SG 2-4 (Upper Bin Includes 1 Cycle 11 data point from SG 2-1 and 3 Cycle 10 data points from SG 2-4) | | | |
|---|---|---|---|
| Growth in Volts/EFPY | BOC Voltage | | |
| | <=0.59V | 0.59V to 1.66V[1] | >1.66V[2] |
| 0 | 48 | 8 | 0 |
| 0.1 | 307 | 39 | 0 |
| 0.2 | 220 | 47 | 2 |
| 0.3 | 79 | 34 | 2 |
| 0.4 | 24 | 22 | 2 |
| 0.5 | 5 | 28 | 0 |
| 0.6 | 8 | 13 | 1 |
| 0.7 | 5 | 14 | 0 |
| 0.8 | 3 | 5 | 0 |
| 0.9 | 0 | 4 | 1 |
| 1 | 1 | 7 | 0 |
| 1.1 | 0 | 7 | 0 |
| 1.2 | 0 | 4 | 0 |
| 1.3 | 1 | 2 | 0 |
| 1.4 | 0 | 6 | 0 |
| 1.5 | 0 | 1 | 1 |
| 1.6 | 0 | 5 | 3 |
| 1.7 | 1 | 0 | 0 |
| 1.8 | 0 | 0 | 1 |
| 1.9 | 0 | 3 | 1 |
| 2 | 0 | 1 | 1 |
| 2.1 | 0 | 0 | 0 |
| 2.2 | 0 | 0 | 0 |
| 2.3 | 0 | 3 | 1 |
| 2.4 | 0 | 1 | 0 |
| 2.5 | 0 | 1 | 1 |
| 2.6 | 0 | 2 | 0 |
| 2.7 | 0 | 0 | 1 |
| 2.8 | 0 | 0 | 0 |
| 2.9 | 0 | 0 | 0 |
| 3 | 0 | 0 | 1 |
| 3.1 | 0 | 0 | 1 |
| 11.8 | 0 | 0 | 0 |
| 11.9 | 0 | 0 | 0 |
| 12 | 0 | 0 | 1 |
| >12 | 0 | 0 | 0 |
| **Total** | **702** | **257** | **21** |

1) Includes 0.06 V/EFPY increase from Cycle 11 actual growth values.
2) Includes 0.08 V/EFPY increase from Cycle 11 actual growth values.

**Table 11-3: DCPP-Specific POPCD**

| Parameter | LogLogistic |
|---|---|
| Number of Data Points | 4688 |
| a.0 (intercept) | 1.644 |
| a.1 (slope) | 4.659 |
| V11 | 0.00522 |
| V12 | 0.01043 |
| V22 | 0.02654 |
| Deviance | 5221 |
| MSE | 0.1890 |
| Binary | TRUE |
| Chi Sqr | 885.5 |
| DoF | 4686 |
| p-Value | <2.9E-07 |

**Table 11-4: Revised DCPP Unit 2 Summary of Calculations of Leak Rate and Burst Probability at EOC-12**

| Steam Generator | Number of Indications at EOC-12 | Probability of Burst | | SLB Leak Rate |
|---|---|---|---|---|
| | | Best Estimate | 95% UCL (1 or More Failures) | (gpm) |
| SG 2-1 | 912.5 | $7.88 \times 10^{-4}$ | $8.56 \times 10^{-4}$ | 0.71 |
| SG 2-2 | 691.4 | $8.06 \times 10^{-4}$ | $8.75 \times 10^{-4}$ | 0.60 |
| SG 2-3 | 689.1 | $6.40 \times 10^{-4}$ | $7.02 \times 10^{-4}$ | 0.48 |
| SG 2-4 | 1670.4 | $5.76 \times 10^{-3}$ | $5.94 \times 10^{-3}$ | 2.86 |
| Reporting Threshold | | | $1.0 \times 10^{-2}$ | 10.5 |

Notes:

(1) Includes AONDB assigned bobbin voltages.

(2) The 95% Upper Confidence Limit (UCL) is based on the number of trials with one or more failures.

(3) Equivalent volumetric rate at room temperature.

(4) The calculated total leak rate reflects the upper 95% quartile value at an upper 95% confidence bound.

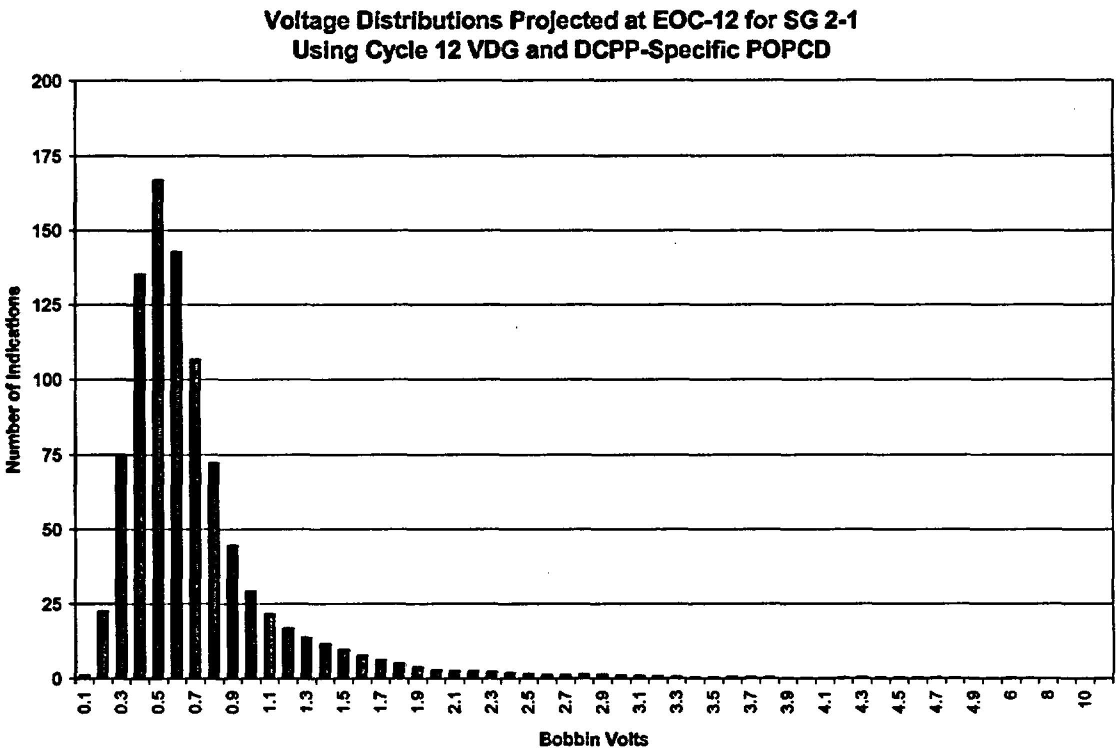
(5) The reference leak limits (10.5 gpm) considers contributions from other ARCs. Therefore other ARC Leak rates should be added to the results in this table to assess total leakage.

**Table 11-5**

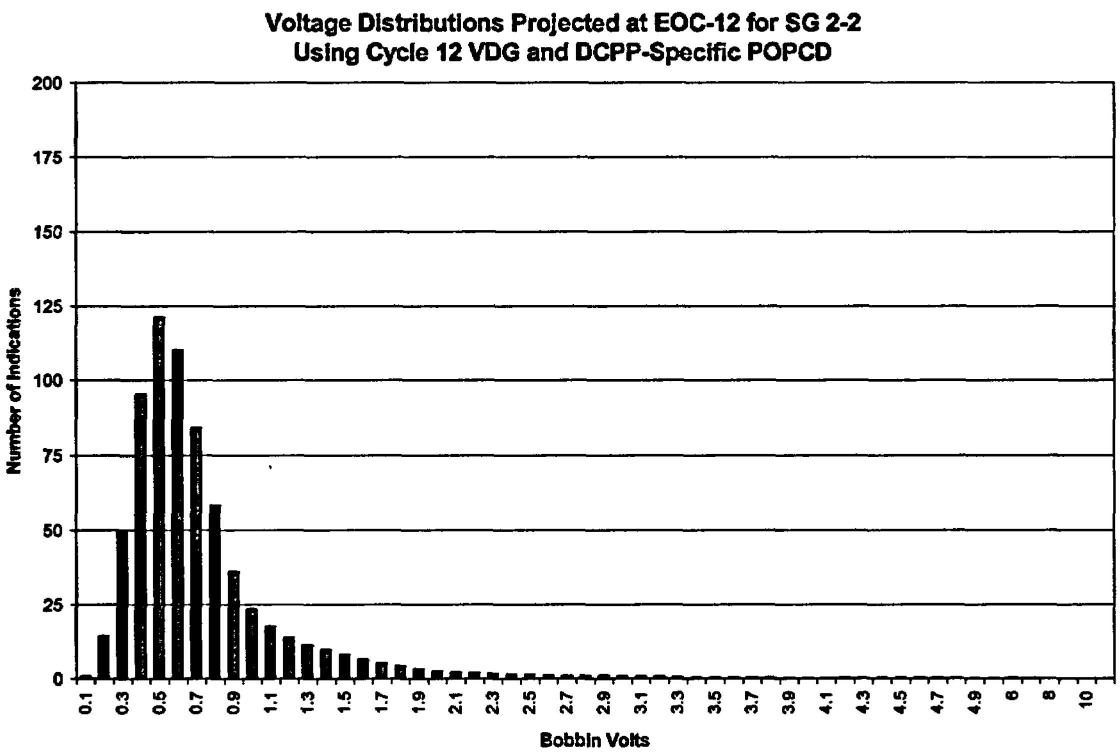
| Voltage Bin | EOC-12 Projected Distributions with VDG and DCPP POPCD | | | |
|---|---|---|---|---|
| | SG 2-1 | SG 2-2 | SG 2-3 | SG 2-4 |
| 0.1 | 1.10 | 0.68 | 0.89 | 0.46 |
| 0.2 | 22.19 | 14.15 | 17.46 | 10.60 |
| 0.3 | 74.20 | 49.46 | 56.49 | 51.63 |
| 0.4 | 135.04 | 95.13 | 99.44 | 131.81 |
| 0.5 | 166.68 | 121.01 | 127.95 | 215.95 |
| 0.6 | 142.57 | 109.91 | 110.65 | 252.11 |
| 0.7 | 106.48 | 83.97 | 85.89 | 226.16 |
| 0.8 | 72.00 | 58.05 | 56.09 | 174.82 |
| 0.9 | 44.39 | 35.87 | 34.04 | 121.38 |
| 1 | 28.98 | 23.43 | 21.11 | 81.87 |
| 1.1 | 21.28 | 17.32 | 14.61 | 59.49 |
| 1.2 | 16.49 | 13.66 | 10.99 | 47.36 |
| 1.3 | 13.40 | 11.28 | 8.87 | 39.89 |
| 1.4 | 11.37 | 9.64 | 7.42 | 36.51 |
| 1.5 | 9.49 | 8.02 | 6.24 | 32.91 |
| 1.6 | 7.50 | 6.40 | 4.96 | 27.26 |
| 1.7 | 5.96 | 5.13 | 3.94 | 22.21 |
| 1.8 | 4.78 | 4.11 | 3.15 | 18.25 |
| 1.9 | 3.56 | 3.08 | 2.38 | 14.22 |
| 2 | 2.70 | 2.35 | 1.83 | 10.73 |
| 2.1 | 2.26 | 1.93 | 1.52 | 8.40 |
| 2.2 | 2.20 | 1.80 | 1.48 | 7.63 |
| 2.3 | 2.00 | 1.63 | 1.34 | 7.57 |
| 2.4 | 1.69 | 1.40 | 1.14 | 7.28 |
| 2.5 | 1.41 | 1.20 | 0.92 | 6.53 |
| 2.6 | 1.15 | 0.99 | 0.74 | 5.38 |
| 2.7 | 0.98 | 0.85 | 0.62 | 4.42 |
| 2.8 | 1.19 | 0.97 | 0.76 | 4.60 |
| 2.9 | 1.22 | 0.97 | 0.79 | 4.72 |
| 3 | 0.97 | 0.82 | 0.65 | 4.08 |
| 3.1 | 0.88 | 0.76 | 0.56 | 3.92 |
| 3.2 | 0.77 | 0.65 | 0.50 | 3.62 |
| 3.3 | 0.52 | 0.46 | 0.35 | 2.67 |
| 3.4 | 0.36 | 0.34 | 0.24 | 1.75 |
| 3.5 | 0.36 | 0.31 | 0.23 | 1.36 |
| 3.6 | 0.46 | 0.36 | 0.29 | 1.62 |
| 3.7 | 0.43 | 0.34 | 0.28 | 1.71 |
| 3.8 | 0.32 | 0.28 | 0.21 | 1.46 |
| 3.9 | 0.21 | 0.20 | 0.13 | 1.05 |

| Voltage Bin | EOC-12 Projected Distributions with VDG and DCPP POPCD | | | |
|---|---|---|---|---|
| | SG 2-1 | SG 2-2 | SG 2-3 | SG 2-4 |
| 4 | 0.15 | 0.14 | 0.09 | 0.73 |
| 4.1 | 0.16 | 0.14 | 0.10 | 0.69 |
| 4.2 | 0.32 | 0.25 | 0.19 | 1.20 |
| 4.3 | 0.37 | 0.28 | 0.24 | 1.51 |
| 4.4 | 0.31 | 0.26 | 0.20 | 1.48 |
| 4.5 | 0.27 | 0.24 | 0.16 | 1.37 |
| 4.6 | 0.28 | 0.24 | 0.17 | 1.42 |
| 4.7 | 0.30 | 0.25 | 0.19 | 1.53 |
| 4.8 | 0.23 | 0.19 | 0.15 | 1.29 |
| 4.9 | 0.14 | 0.14 | 0.10 | 0.91 |
| 5 | 0.09 | 0.09 | 0.06 | 0.59 |
| 6 | 0.20 | 0.18 | 0.16 | 1.38 |
| 7 | 0.07 | 0.07 | 0.07 | 0.49 |
| 8 | 0.03 | 0.01 | 0.01 | 0.15 |
| 9 | 0.01 | 0.00 | 0.00 | 0.04 |
| 10 | 0.00 | 0.00 | 0.00 | 0.02 |
| >10 | 0.02 | 0.02 | 0.02 | 0.18 |
| **Total** | **912.49** | **691.41** | **689.08** | **1670.36** |

## Figure 11-1

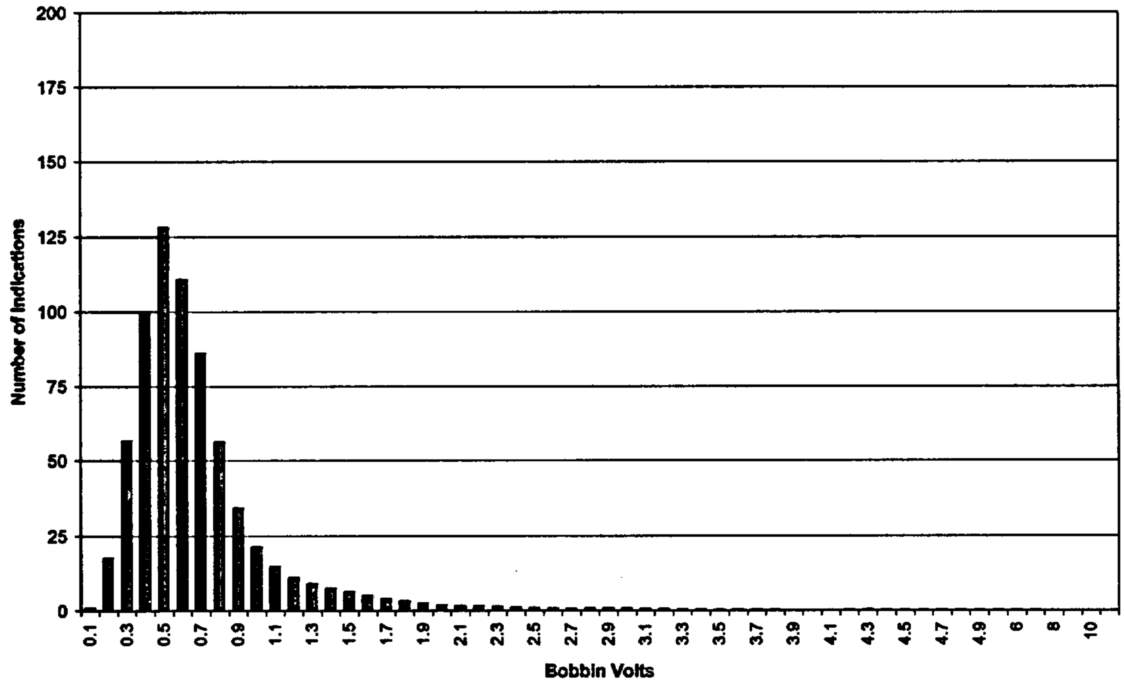



## Figure 11-2



## Figure 11-3

**Voltage Distributions Projected at EOC-12 for SG 2-3
Using Cycle 12 VDG and DCPP-Specific POPCD**




## Figure 11-4

**Voltage Distributions Projected at EOC-12 for SG 2-4
Using Cycle 12 VDG and DCPP-Specific POPCD**