NRC FORM 658
(9-1999)

U.S. NUCLEAR REGULATORY COMMISSION

TRANSMITTAL OF MEETING HANDOUT MATERIALS FOR IMMEDIATE PLACEMENT IN THE PUBLIC DOMAIN

This form is to be filled out (typed or hand-printed) by the person who announced the meeting (i.e., the person who issued the meeting notice). The completed form, and the attached copy of meeting handout materials, will be sent to the Document Control Desk on the same day of the meeting; under no circumstances will this be done later than the working day after the meeting.
Do not include proprietary materials.

DATE OF MEETING: 3/4/03

The attached document(s), which was/were handed out in this meeting, is/are to be placed in the public domain as soon as possible. The minutes of the meeting will be issued in the near future. Following are administrative details regarding this meeting:

Docket Number(s): 50-323

Plant/Facility Name: Diablo Canyon Unit 2

TAC Number(s) (if available): MB7694

Reference Meeting Notice: MB030580504

Purpose of Meeting (copy from meeting notice): To present resolution of steam generator issues from the current refueling outage 2R11.

NAME OF PERSON WHO ISSUED MEETING NOTICE	TITLE
G. S. SHUKLA x8439	Project Manager

OFFICE: NRR / DLPM

DIVISION: DLPM

BRANCH: PD IV-2

Distribution of this form and attachments:
Docket File/Central File
PUBLIC

DF01

Introduction

- PG&E has experienced two unexpected and industry significant SG inspection results
- Overall, we believe our SG tube integrity program is strong and that the program worked
- We have gained several insights that will help the industry manage SG tube integrity
- PG&E will present in this meeting an analysis and justification to return Unit 2 to service and an operational assessment for at least 120 days of operation
- We will also discuss our evaluation of Unit 1 operability and our plans for full cycle operation of Unit 2
- We believe we have responded correctly and conservatively to both issues

PG&E

DCPP Unit 2 Steam Generator Issues

Operational Assessment and Cause Analysis

March 4, 2003

PG&E

Agenda

- Background
  - Inspection scope and results
- Startup Issue – ODSCC Voltage Growth
  - Review GL 95 05 ARC Requirements
  - As found vs. predicted results
  - Problem statement and proposed solution
  - Crack growth and Voltage Dependent Growth concepts
  - Modified POD for R44C45 2H flaw
  - Startup calculations and assumptions
  - Benchmarking
  - Operational assessment for >120 days
  - Root cause analysis

PG&E

Agenda

- Locked TSP update
- Risk assessment
- Other PG&E actions for this issue
- Plans for cycle beyond 120 days

- Second Issue – U bend indications
  - Background
  - Inspection scope and results
  - Summary of indications and locations
  - Morphology
  - Historical data review
  - Visual inspection results
  - In-situ leak and pressure test results

PG&E

Agenda

- Root cause analysis
- Future plans
- Requested NRC actions
- Break/caucus
- Feedback from staff
- Unit 1 operability
- DCPP POPCD description and justification
- Caucus
- Feedback from staff

PG&E

Background

- DCPP – Westinghouse Model 51 SGs
  - A600MA tubing
  - 14+ EFPY
  - 3 ARCs (ODSCC, PWSCC, W*)
- 2R11 – a "normal" SG Inspection
  - ECT scope (typical)
    - 100% bobbin, extensive +point (TTS, dents, row 1 and 2 U bends, etc)
  - Small P/S leak since late in cycle 9 – did not find in 2R9 or 2R10
  - Planned secondary pressure test (200-800 psi) in SG 2-4 (expanded to all)

PG&E

Background

- Expanded ECT program
  - CL TTS +point (100% 2-4, 20% in others)
  - Row 3 U bends +point (100% 2-4, 20% in others)
- First results came from pressure test
  - 15 “leaking” tubes
  - ECT of leaking tubes found two issues
    - Large ODSCC flaw
    - U bend circumferential indications in a row 5 U bend

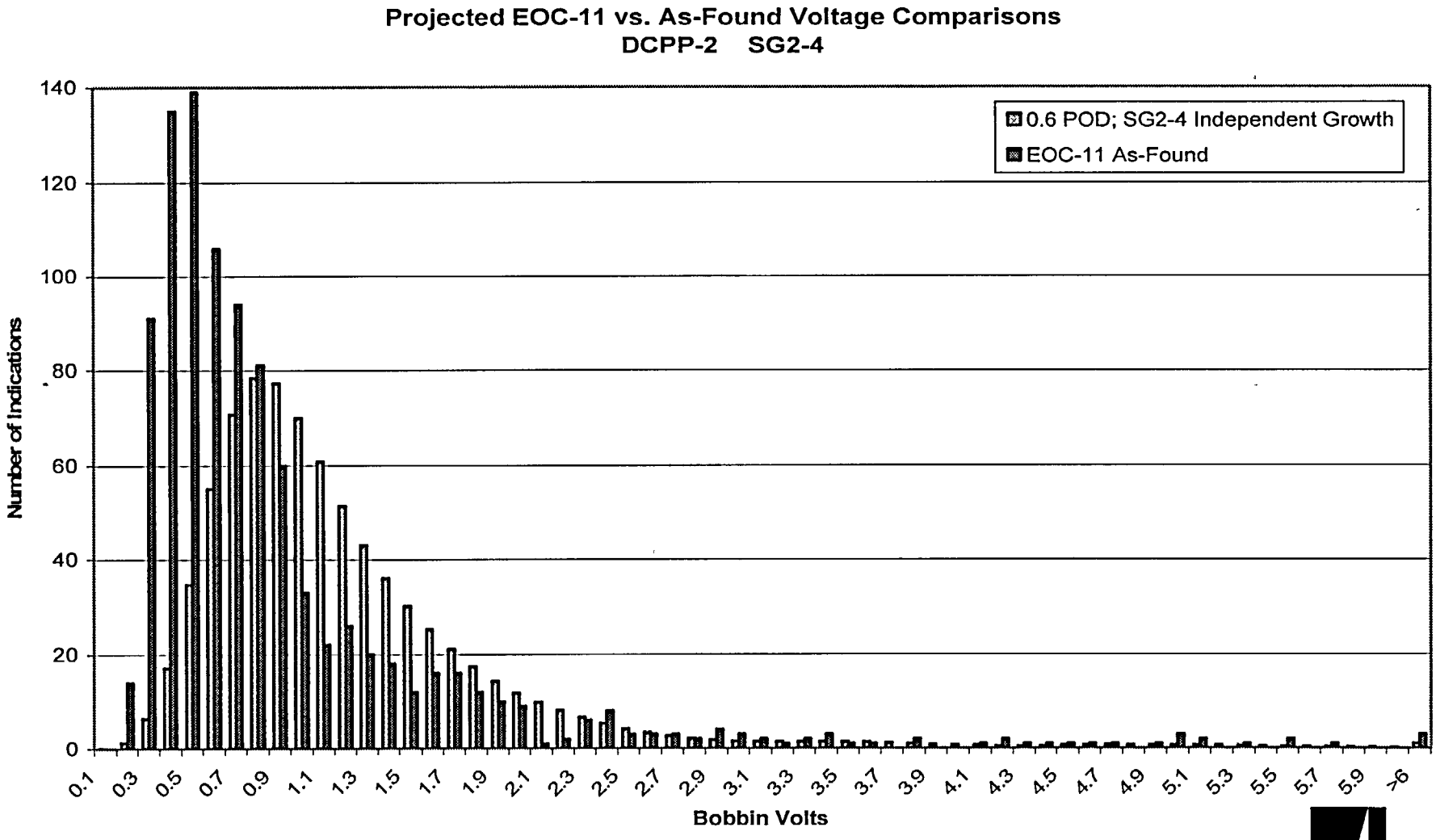
PG&E

Review of GL 95 05

- Implemented Unit 1-1R9 and Unit 2-2R8
- Criteria: POB 1E-02, accident induced (combined ARC) leakage 10.5 gpm
- Requires use of 0.6 POD for flaw detection
- Operational Assessment (OA) using Monte Carlo simulation to show performance criteria met at end of planned operating period
- Predictions use burst and leak correlations from EPRI Database (now Rev 5) – approved by NRC
- 90 day report to NRC reporting Condition Monitoring (CM) and OA results
- Addendum includes assessment of VDG (voltage dependent growth) – non NRC reviewed

PG&E

2R11 Inspection Results



SG 2-4 As Found Condition

SG 2-4 EOC 11 POB Calculation Comparisons					
Calculation	POD	Growth	Addendum	Delta Pressure	Result
90 day Report	0.6	Independent	4	2560	1.30E-03
		2 Bin VDG			3.66E-03
	Add 4 POPCD	Independent	4	2560	6.12E-04
		2 Bin VDG			1.64E-03
Recalculated 90 day Report	0.6	3 Bin VDG	5	2405	8.40E-03
	DCPP POPCD	3 Bin VDG			3.63E-03
As Found	NA	NA	5	2405	2.50E-02
As Found (w/o 21.5v Flaw)	NA	NA	5	2405	3.97E-03

PG&E

Problem Statement and Proposed Solution

- Where we were/are:

  The POB criteria is not satisfied for startup or any operating period for Unit 2 using a 0.6 POD and large flaw(s) found in 2R11. The conservatism of previous flaw growth prediction methods was in question – and a concern.
- Solutions proposed:
  - Modify POD
    - Short term – use POD of 1.0 for largest flaw
    - Longer term – POPCD
  - Investigate, understand and implement enhanced VDG methodology (with/without 21.5 volt flaw)
    - Verify that VDG methods are technically correct, statistically valid and conservative
  - Administratively plug tubes at lower bobbin voltage
  - Appropriately benchmark methods

PG&E

Crack Growth and Voltage Dependent Growth Evaluation Objectives

- Review fundamental principles affecting voltage growth rates
- Review and assess domestic and international experience with voltage growth rates including models for voltage growth
- Assess causative factors for large voltage increase in DCPP-2 R44C45
- Review and assess DCPP-2 voltage growth rates based on international experience with voltage growth
- Assess need for increasing 2R11 voltage growth distributions for 2R12 and define adjustments if required

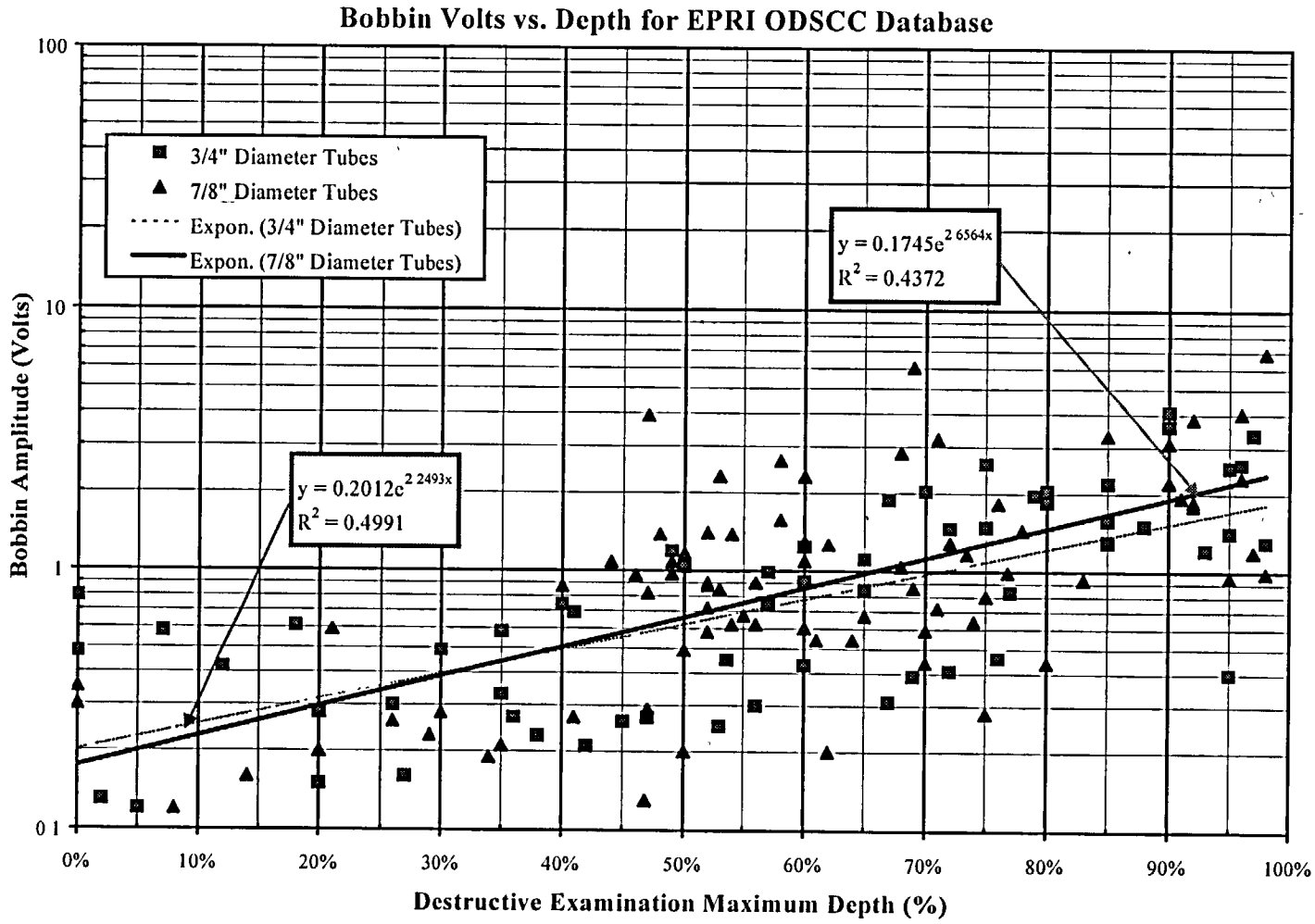
PG&E

General Considerations for Voltage Growth Rates

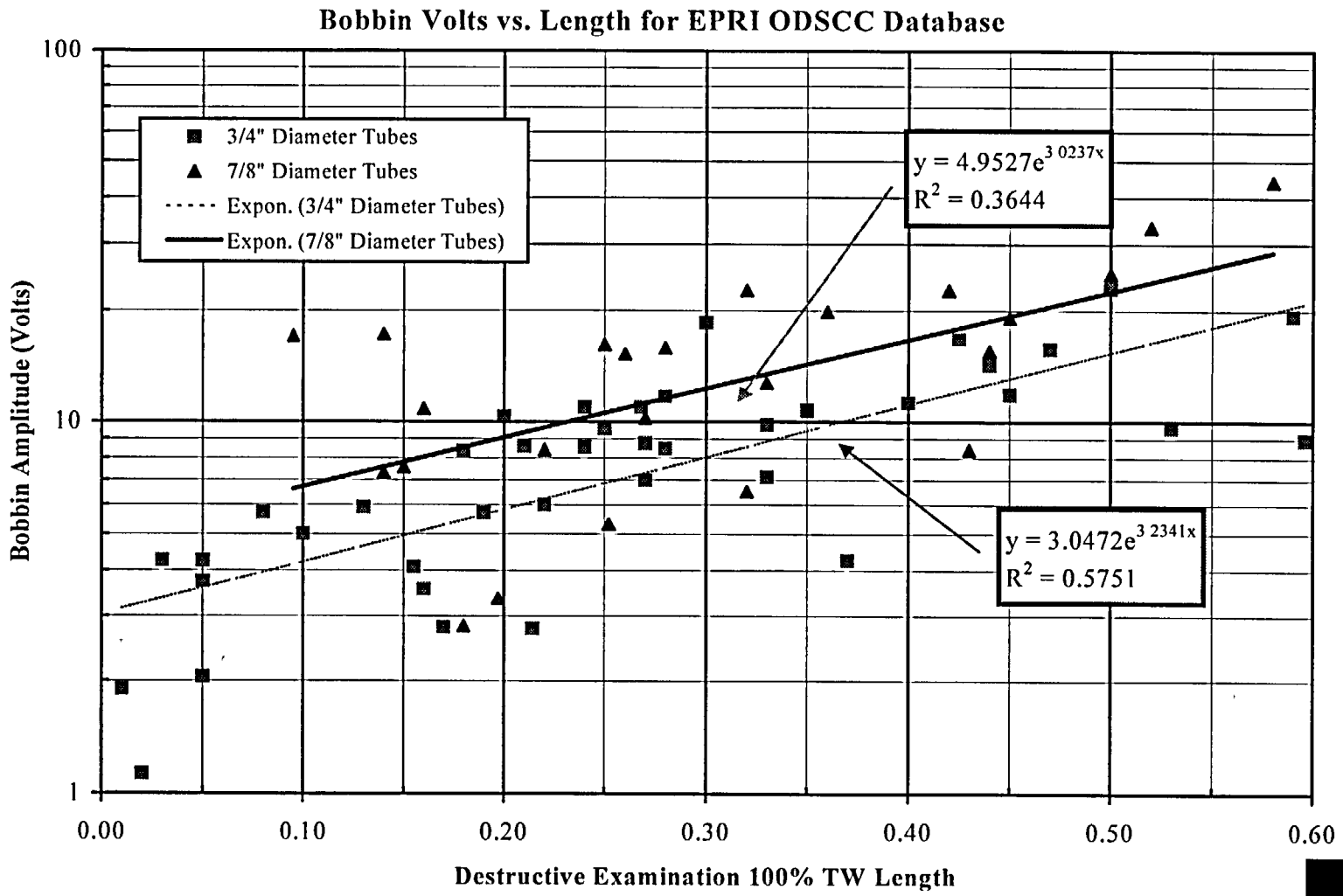
- Large increases in voltage growth rates do not imply similar increases in depth growth rates
  - Voltage increases exponentially with depth
  - Voltage further increases exponentially with TW length after 100% depth reached
  - Increases in voltage growth rates with an increase in population above about 1.0 volt can be expected based upon exponential increase in voltage with depth even if growth in depth is constant

PG&E

Bobbin Volts vs. Depth for EPRI ODSCC Database



Bobbin Volts vs. TW Length for EPRI Database



General Considerations for Voltage Growth Rates

- Progressive voltage growth increases from cycle to cycle are more dependent upon larger BOC depths than increases in depth growth rates

PG&E

Additional Considerations for Voltage Growth Rates

- Causal factors such as chemistry and temperature increases due to plugging are not a major factor in large voltage increases at DCPP-2
  - Based on multiple plant chemistry reviews conducted following cycles with large voltage growths including DCPP
  - Cycle to cycle temperature increases due to plugging are typically less than one degree which has a small effect on crack growth
  - Large temperature differences between plants, such as 10 degrees or more, can significantly influence growth rate differences between plants

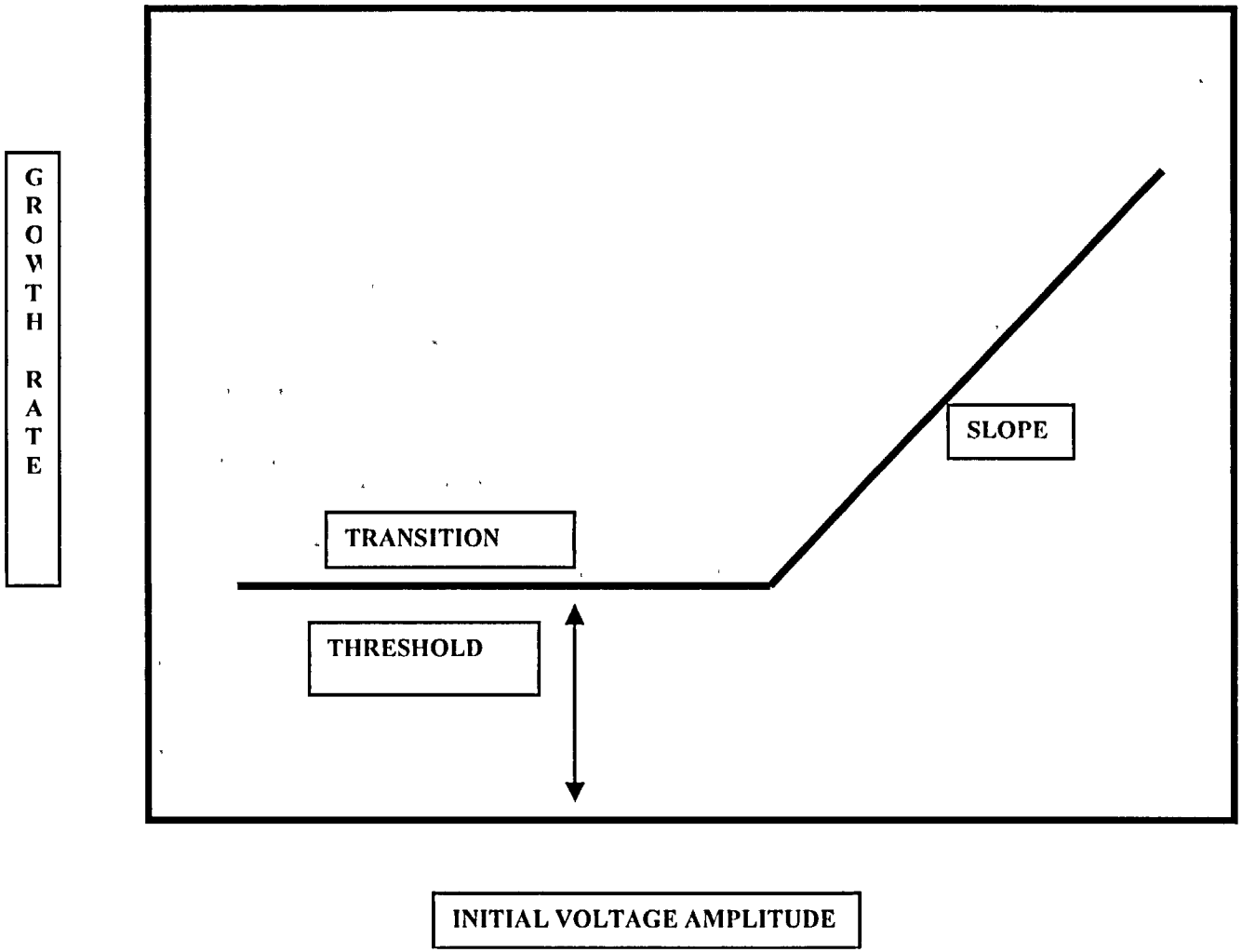
PG&E

Growth Rate Modeling

- Belgian model for voltage growth as function of BOC volts: bilinear model
  - 'Threshold' average growth constant (range of 0.15 to 0.32 volt/EFPY) up to 'transition' voltage
  - Transition typically in range of 0.8 to 1.3 volt
  - Above transition, average growth and standard deviation increase linearly with BOC volts

PG&E

Belgian Voltage Growth Model



Growth Rate Modeling

- Belgian bilinear model similar in application to EPRI recommended voltage dependent growth method
  - Domestic lowest voltage growth distribution up to about 1.0 volt tends to be relatively constant with time
  - Voltage growth rates for BOC volts above 1.0 to 1.5 volts tend to show increasing growth rate as the population voltages increase with time
  - Voltage bins should be selected to obtain an adequate number of growth values in a bin to reflect a reasonable probability for the larger growth rates

PG&E

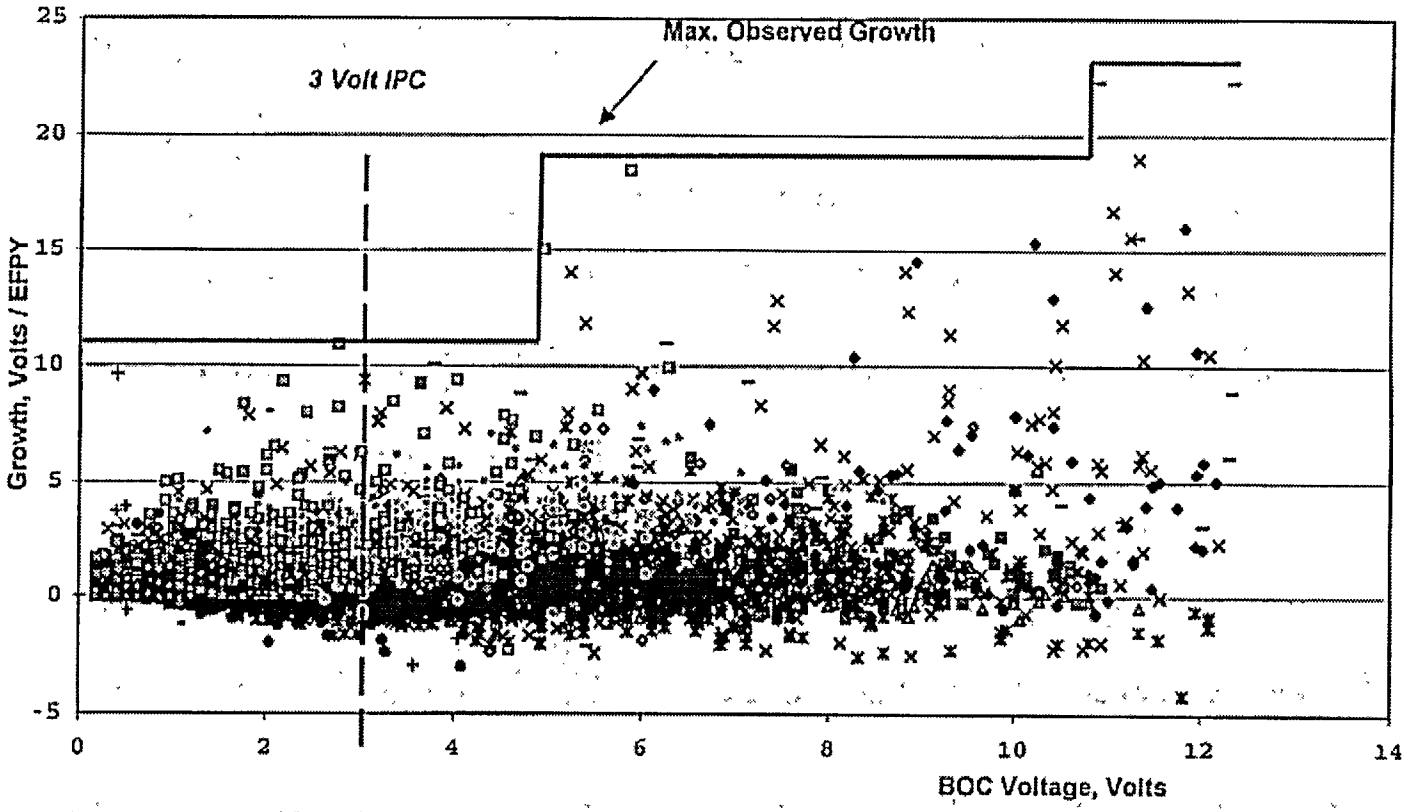
Maximum Voltage Growth per EFPY

- Largest Growth Rate Based on European Growth Data
  - European growth data given in EPRI database Addendum 2
  - Data provide an upper bound on growth rate
  - Maximum growth bounded by about 11 volts/EFPY for BOC voltages up to about 5 volts
- DCPP-2 Maximum Voltage Growth
  - Maximum growth rate of 11.8 volts for SG 2-4 R44C45

PG&E

Combined European Data, Growth vs BOC

Combined European Data, Growth Vs BOC (23,700 Data Points)



Conclusion: 1. Braidwood & U.S. Growth Within European Data
2. Growth is not increasing in 1.5 - 3 Volt Range

Note: Normalized to Braidwood 1 T-Hot

Maximum Voltage Growth per EFPY

- Maximum Voltage Growth Rates in Other Domestic Plants
  - 7/8" tubing
    - Plant A-1: 7.0 volts/EFPY
  - 3/4" tubing
    - Plant AA-1: 9.6 volts/EFPY (8.1 volts in prior cycle)
    - Plant AB-1: 8.1 volts/EFPY
    - Plant AC-1: 8.6 volts/EFPY

PG&E

Maximum Voltage Growth per EFPY

- Implications of largest growth rate experience
  - All domestic and European growth experience show maximum growth below about 5 BOC volts bounded by about 11 volts
  - No further increases in largest growth rate would be expected in the next operating cycle
  - Estimates for voltage growth in Cycle 12 do not require an increase in the maximum growth rate

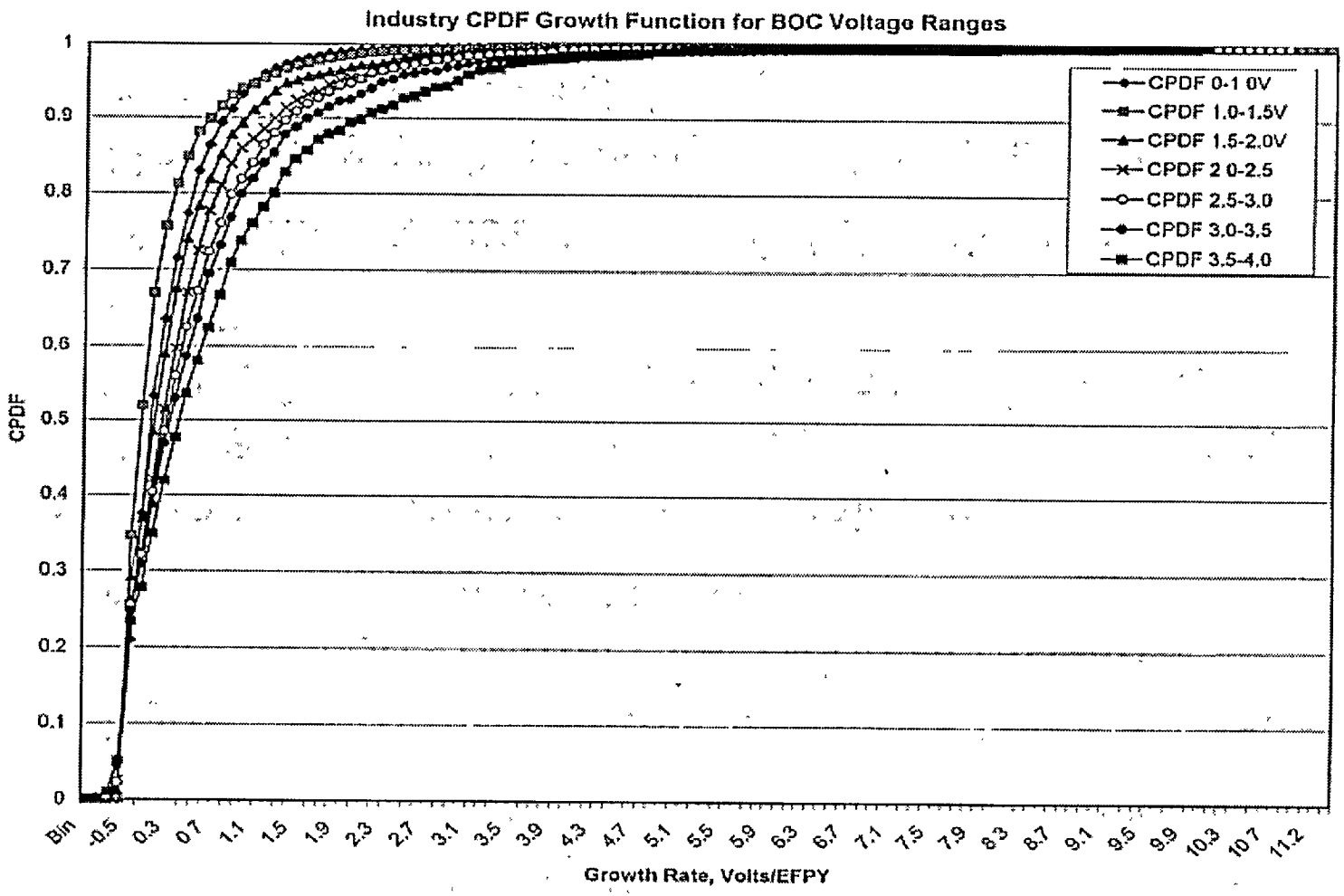
PG&E

European Voltage Dependent Growth Experience

- Larger European repair limits and large number of indications permit evaluation of growth dependence on BOC volts
- Large population of higher voltage BOC indications show that increases in growth rates with BOC voltage occur as small, well defined steps
  - Data evaluated in BOC 0.5 volt bins
- No large step increases in voltage bin growth rates - similar to Belgian model

PG&E

European Voltage Dependent Growth Data

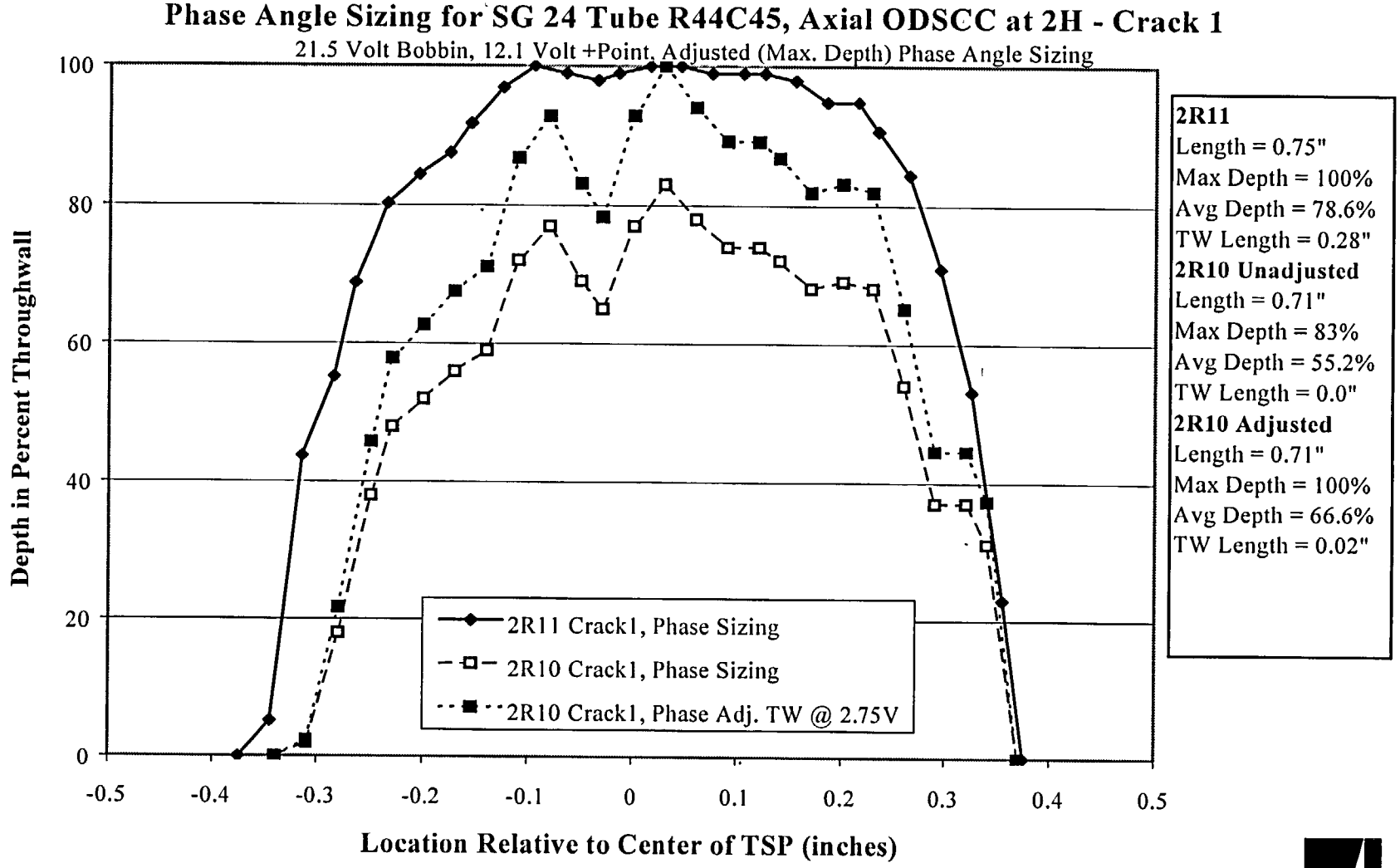


SG 2-4 R44C45 Crack Growth Considerations

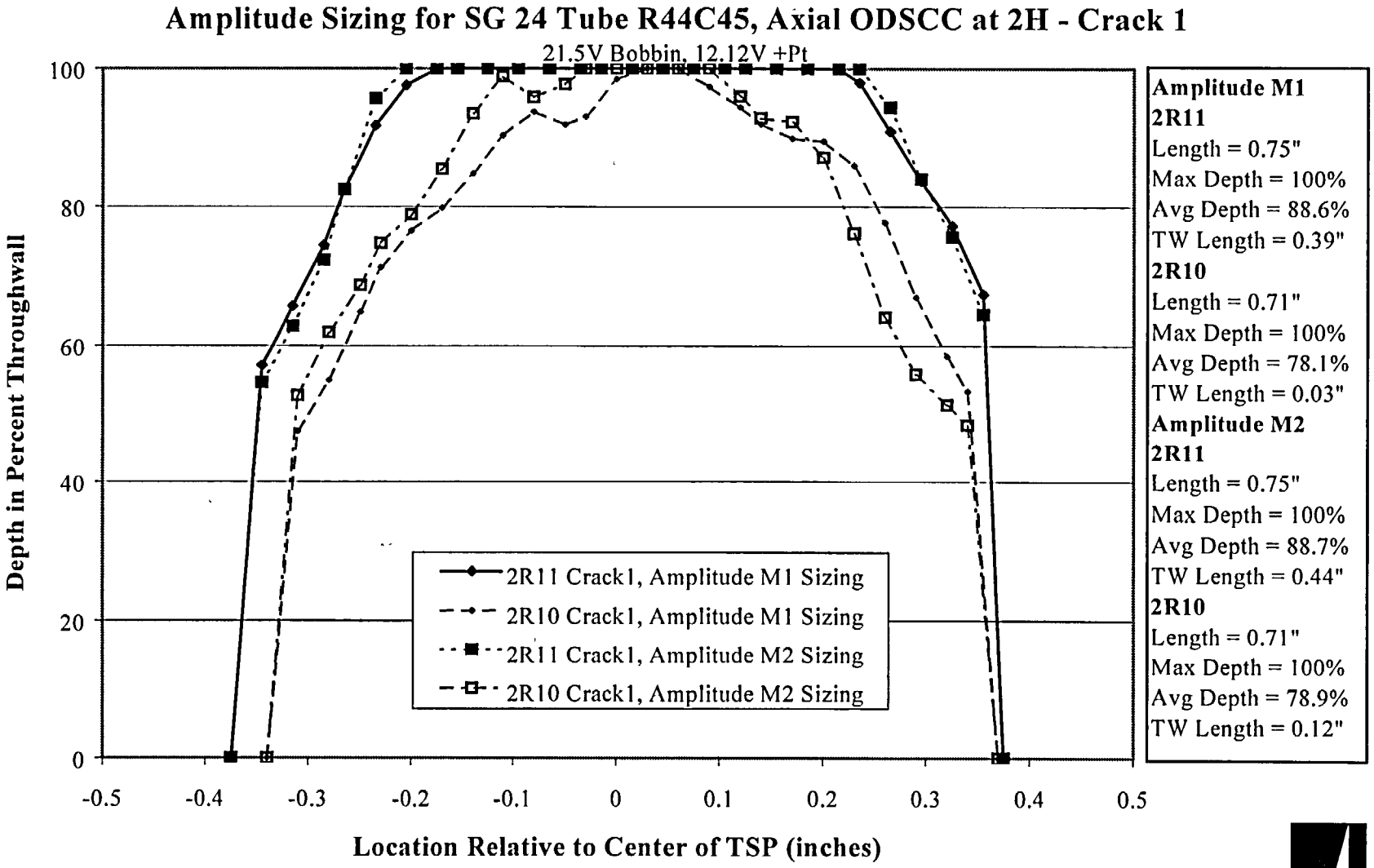
- NDE Depth Sizing for SG 2-4 R44C45
  - Indications at 2R11 and 2R12 sized by phase angle and amplitude methods
  - Phase sizing
    - Adjustment methods applied similar to that included in DCPP PWSCC ARC
    - Depth adjustments: ODSCC depth profile scaled to 100% if +Point maximum volts > 2.75 volts (4 volts for PWSCC ARC) based on high probability that indication is through-wall
    - R44C45 - 12.2 volts at 2R11 and 2.97 volts at 2R10
  - Indication believed to be incipient through-wall or through-wall at 2R10 and through-wall in the range of 0.3 to 0.45 inch at 2R11
  - Growth in average depth of 12% from phase sizing and 10% from amplitude sizing

PG&E

Phase Sizing for SG 2-4 Tube R44C45
2R10 and 2R11



Amplitude Sizing for SG 2-4 Tube R44C45 2R10 and 2R11

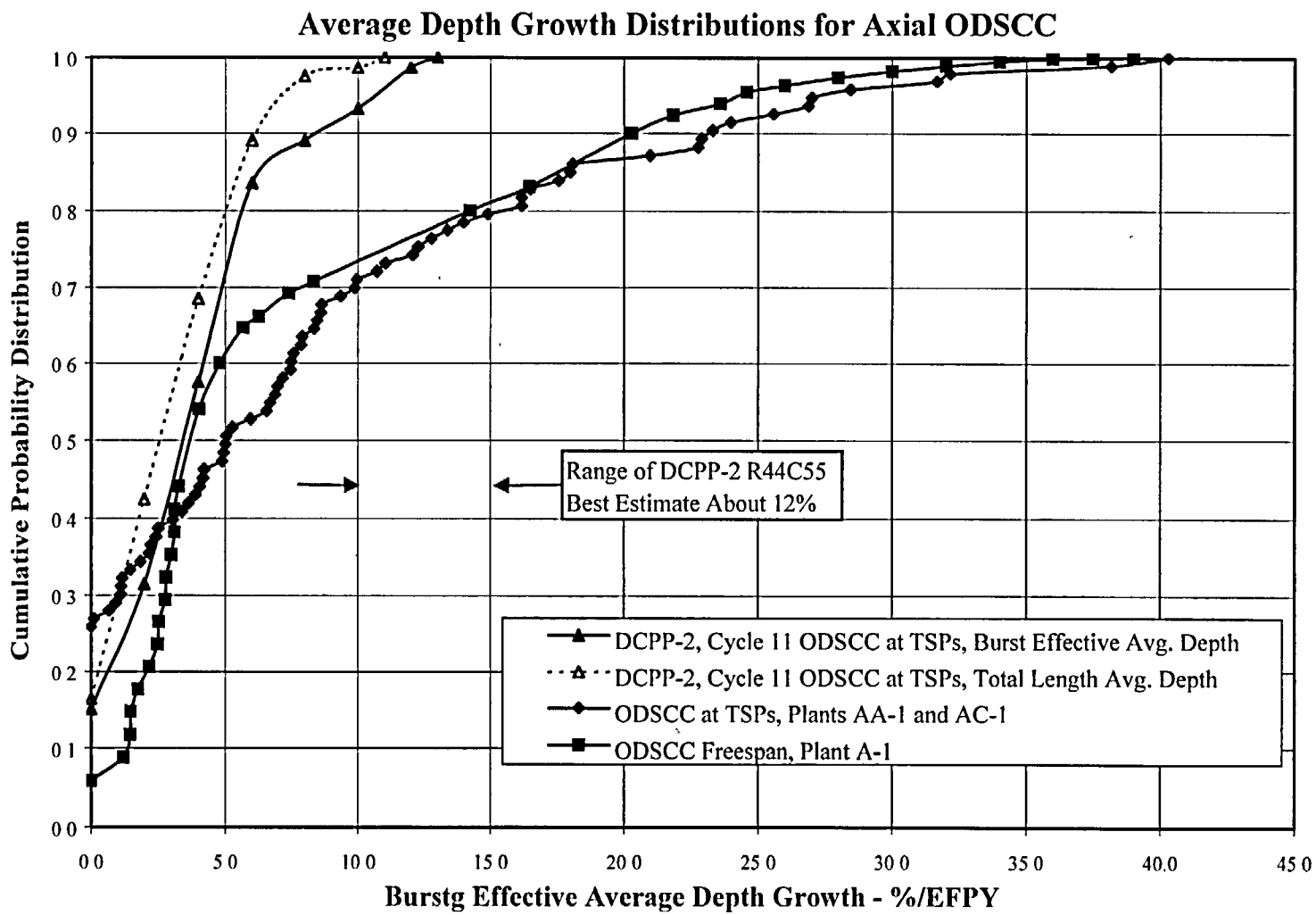


SG 2-4 R44C45 Crack Growth Considerations

- Comparison of R44C45 Average Depth Growth with Other Axial ODSCC Distributions
  - Growth distributions available for freespan and TSP intersection indications
    - Plants with large growth rates that successfully operated a full cycle following occurrence of large ODSCC indications
  - R44C45 average depth growth of about 12% corresponds to about 75% cumulative probability for large growth rate distributions
- **Conclusion**: R44C45 does not have a large growth rate in depth

PG&E

Average Depth Growth Distributions for Axial ODSCC



SG 2-4 R44C45 Crack Growth Conclusions

- Basis for large voltage growth increase for R44C45
  - Voltages increase exponentially with depth to through-wall and then exponentially with through-wall length
  - Voltage dependence on through-wall length based on EPRI ODSCC ARC database
- Large voltage increase with modest growth in depth

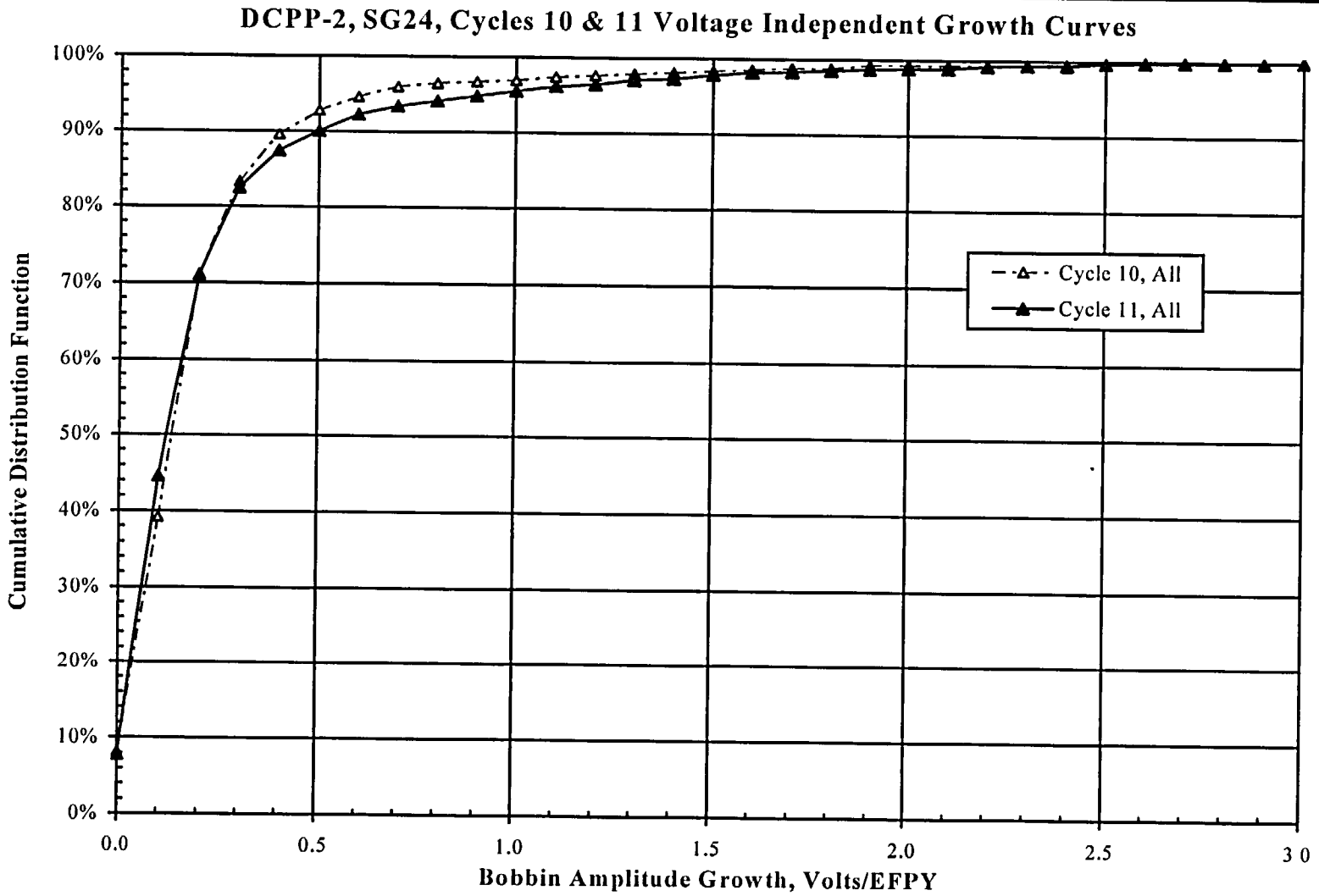
PG&E

DCPP-2 Comparisons of Cycles 10 and 11
Voltage Dependent Growth

- SG 2-4: Comparison of Cumulative Distributions for Voltage Independent Growth
  - Cycle 11 growth only slightly greater than Cycle 10 above 85% cumulative probability
  - No indication of a large growth increase for Cycle 11

PG&E

DCPP SG 2-4 Cycles 10 & 11 Voltage Independent Growth

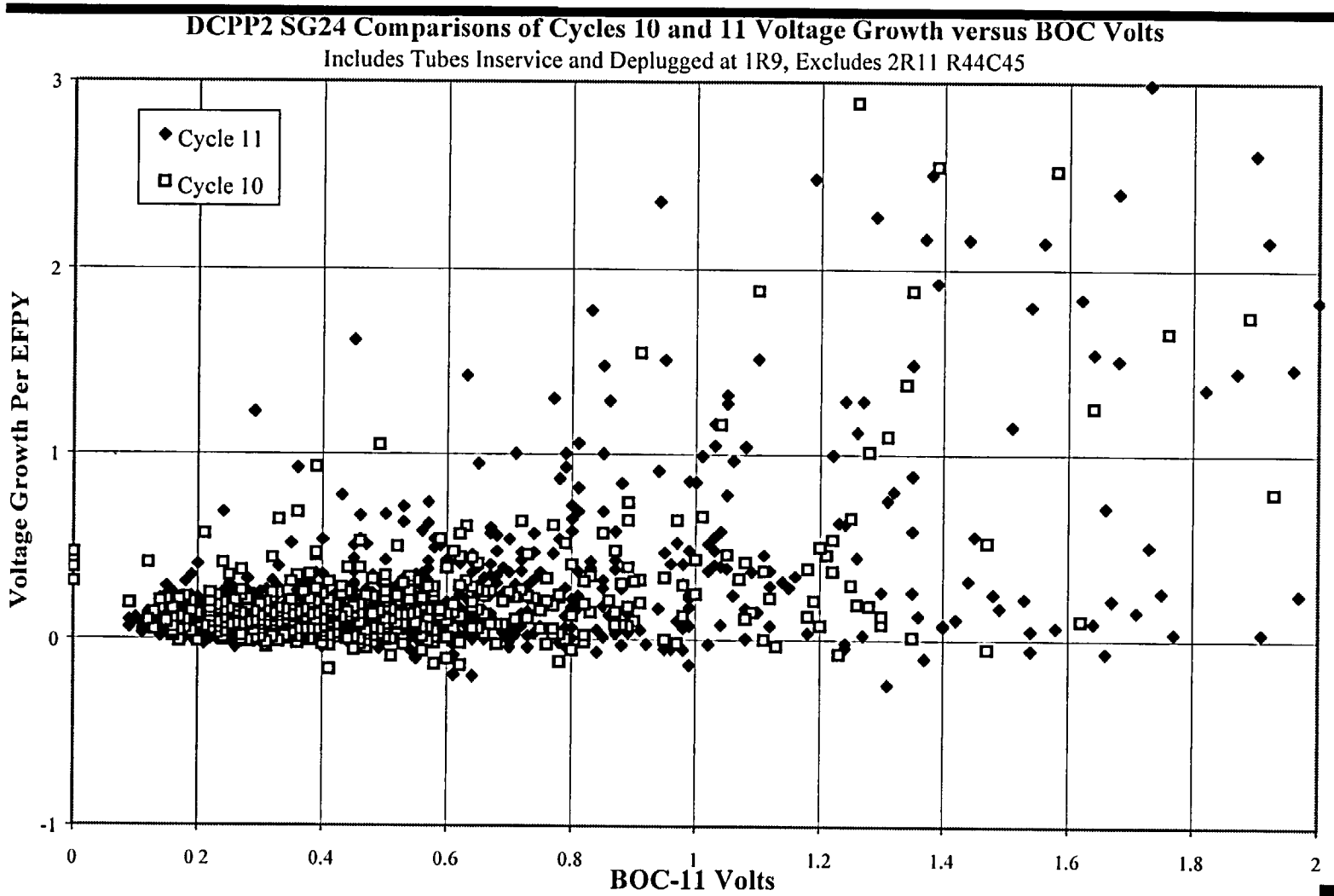


DCPP-2 Comparisons of Cycles 10 and 11, SG 2-4 ΔV/EFPY Versus BOC Volts

- Comparisons exclude R44C45 to facilitate comparisons (limits data to growth < 3 volts/EFPY)
- Differences between Cycles 10 and 11 are modest
- Cycle 11 has larger population at BOC which corresponds to more large growth indications
- Maximum ΔV/EFPY not significantly different between the two cycles

PG&E

DCPP SG24 Cycles 10 & 11 Voltage Growth vs BOC Volts

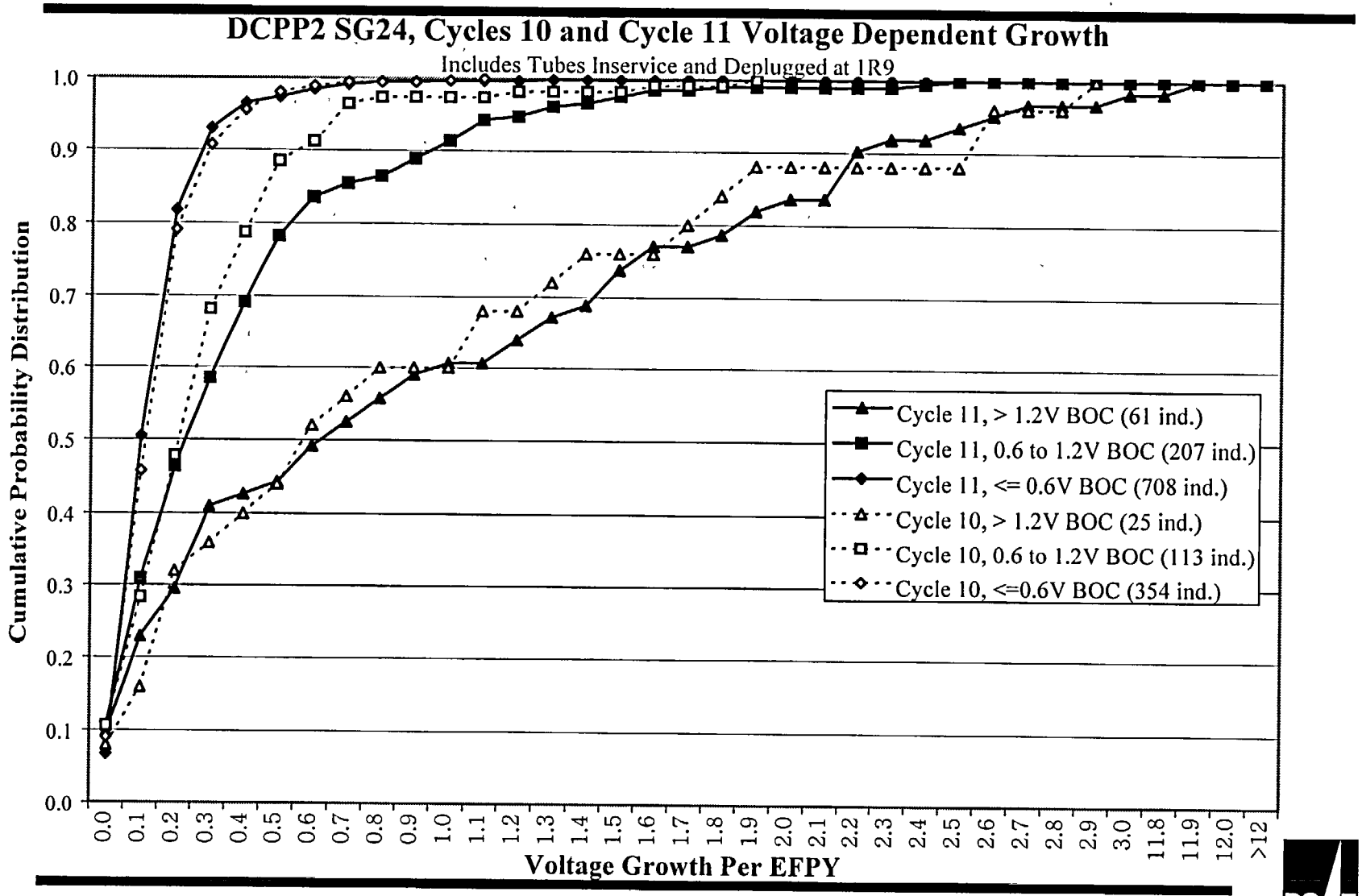


DCPP-2 Comparisons of Cycles 10 and 11 Voltage Dependent Growth

- SG 2-4: Comparison of Cumulative Distributions for Voltage Dependent Growth
  - Above 1.2 volts, Cycles 10 and 11 show approximately the same growth distribution (excluding R44C45 from comparison)
  - For the growth bin between 0.6 and 1.2 volt, Cycle 11 shows moderately larger growths than found in Cycle 11
    - Larger population in Cycle 11 than Cycle 10 contributes to the differences
  - For the growth bin below 0.6 volts, the growth rates are the same for Cycles 10 and 11
  - The growth differences between Cycles 10 and 11 are modest (except for R44C45)

PG&E

DCPP SG24 Cycles 10 & 11 Voltage Dependent Growth



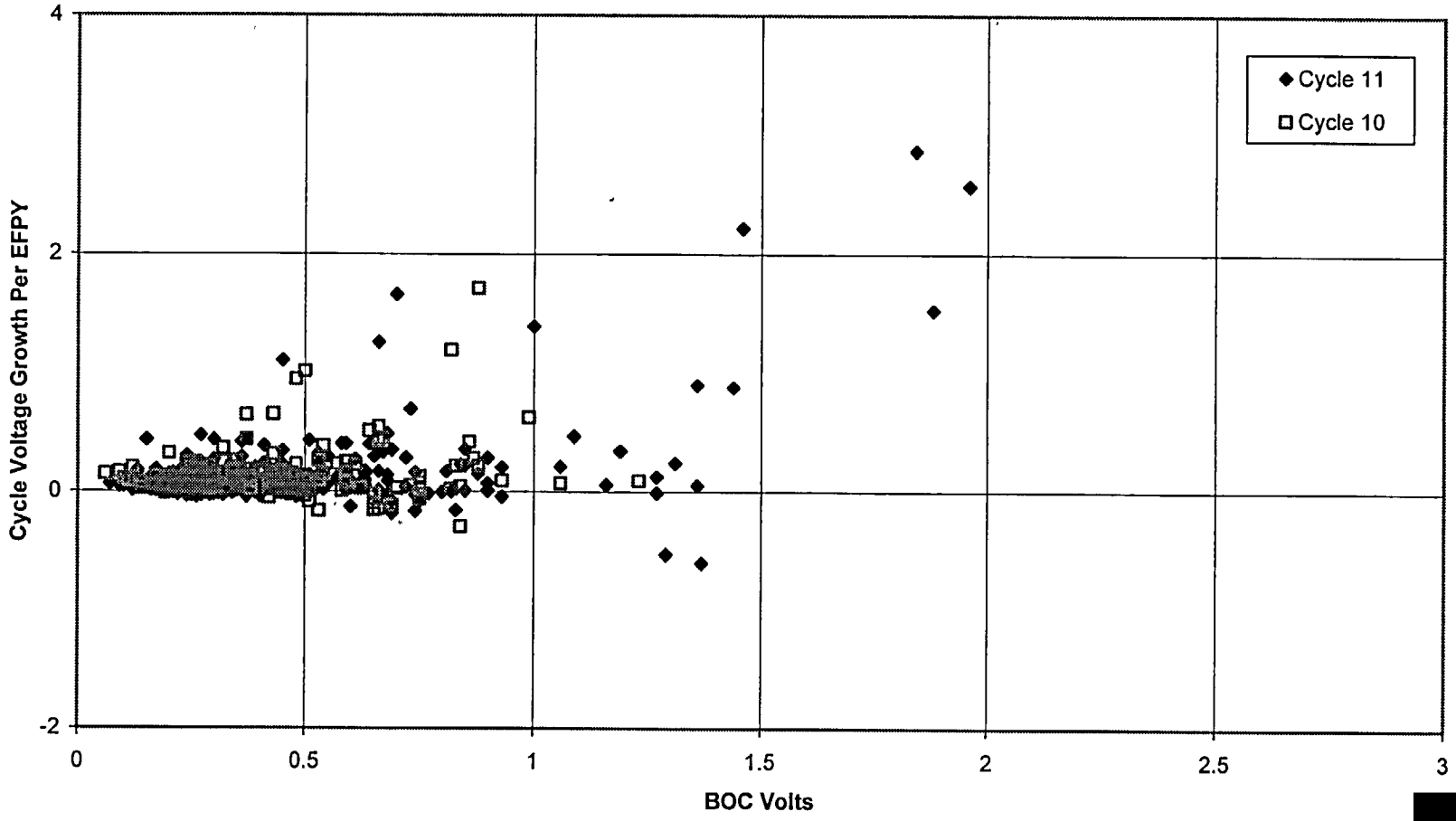
PG&E

DCPP-2 Comparisons of Cycles 10 and 11 Voltage Dependent Growth

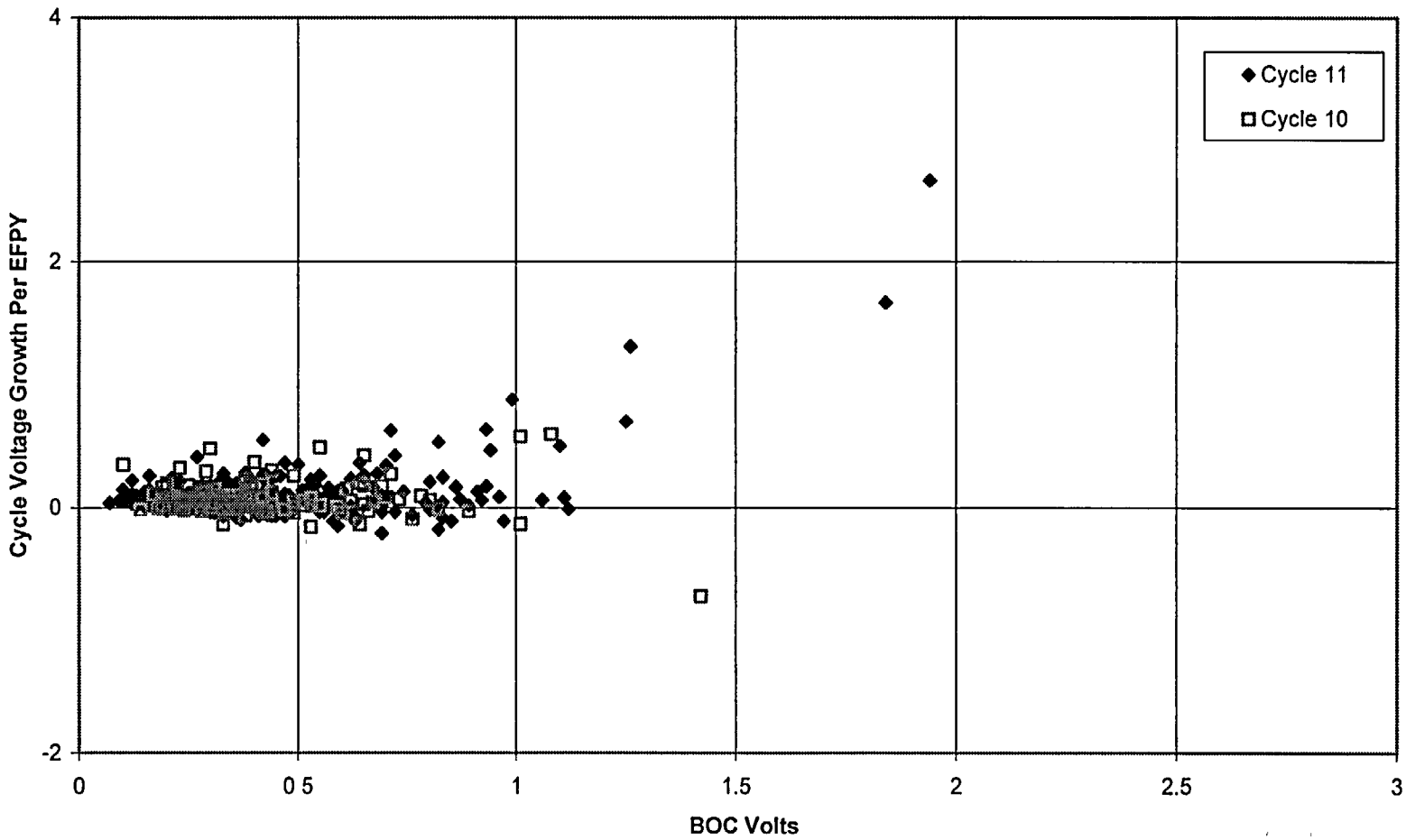
- SGs 2-1, 2-2, 2-3: Growth ΔV/EFPY Versus BOC Volts
  - Voltage dependent growth found in SGs 2-1, 2-2 and 2-3 above about 1 volt with somewhat reduced voltage dependent growth in SG 2-3
  - The small population of indications above about 1.2 volts for these SGs makes it impractical to define a voltage dependent growth distribution for these SGs
  - Application of SG 2-4 growth distributions to SGs 2-1 to 2-3 is appropriate
    - Bounds potential growth for a more 'mature' population in these SGs

PG&E

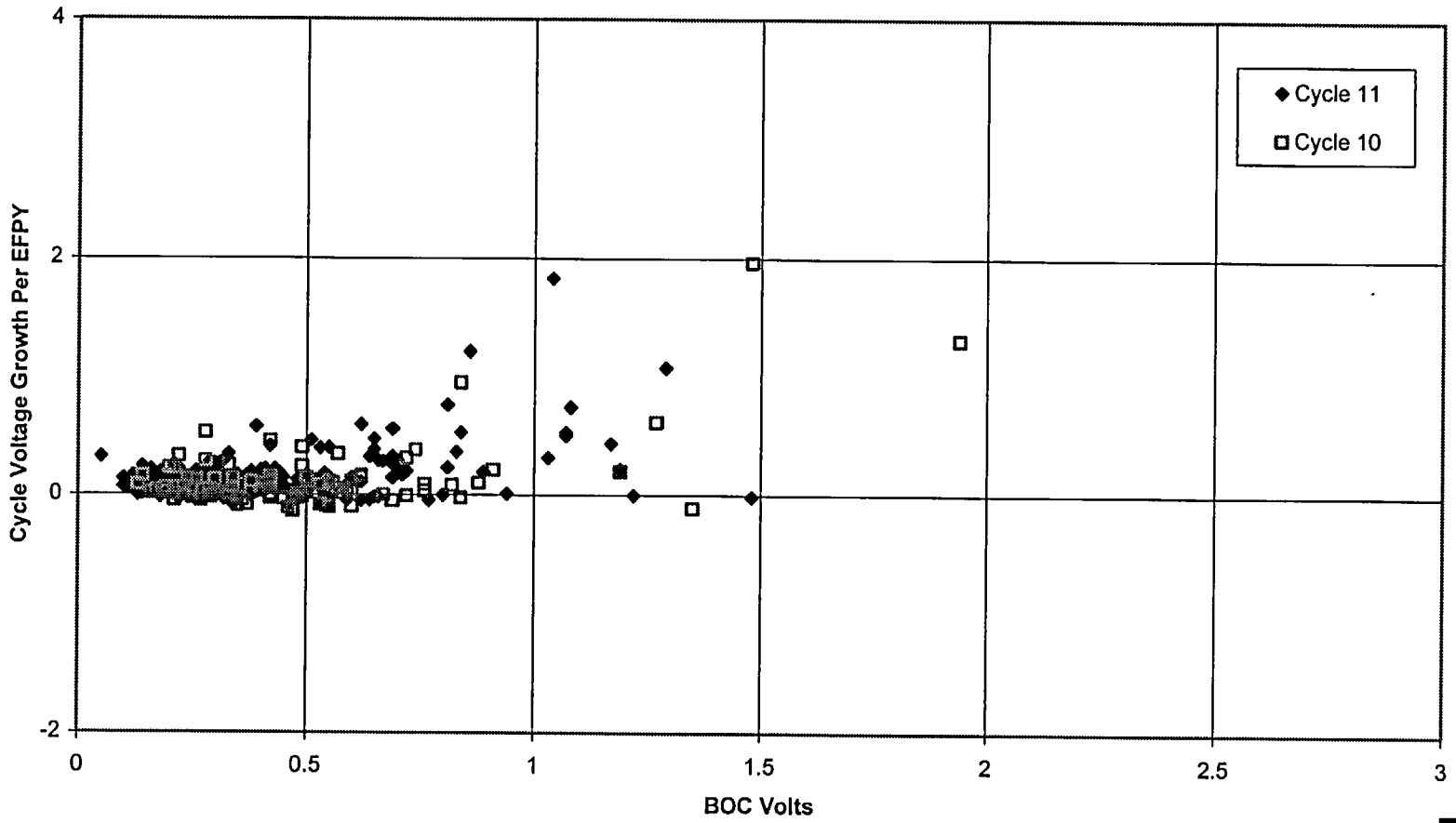
DCPP SG2-1 Cycles 10 & 11 Voltage Growth Dependence on BOC Volts



DCPP SG2-2 Cycles 10 & 11 Voltage Growth Dependence on BOC Volts



DCPP SG2-3 Cycles 10 & 11 Voltage Growth Dependence on BOC Volts



DCPP-2 Comparisons of Cycles 10 & 11 Voltage Dependent Growth

- Conclusions from Comparisons of Cycles 10 and 11 Growth Distributions
  - Cycle 11 does not show a large increase in growth over that found in Cycle 10 except for the R44C45 indication
  - All SGs show growth dependence on BOC voltage although the voltage dependence is not well defined for SGs 2-1, 2-2, and 2-3 due to the small population of indications above about 1.2 volts
  - The lowest (≤ 0.6 volt) and upper voltage bins (> 1.2 volt) shows essentially the same growth distributions between Cycles 10 and 11
  - Only the middle bin (0.6 to 1.2 volt) shows an increase in growth compared to Cycle 10

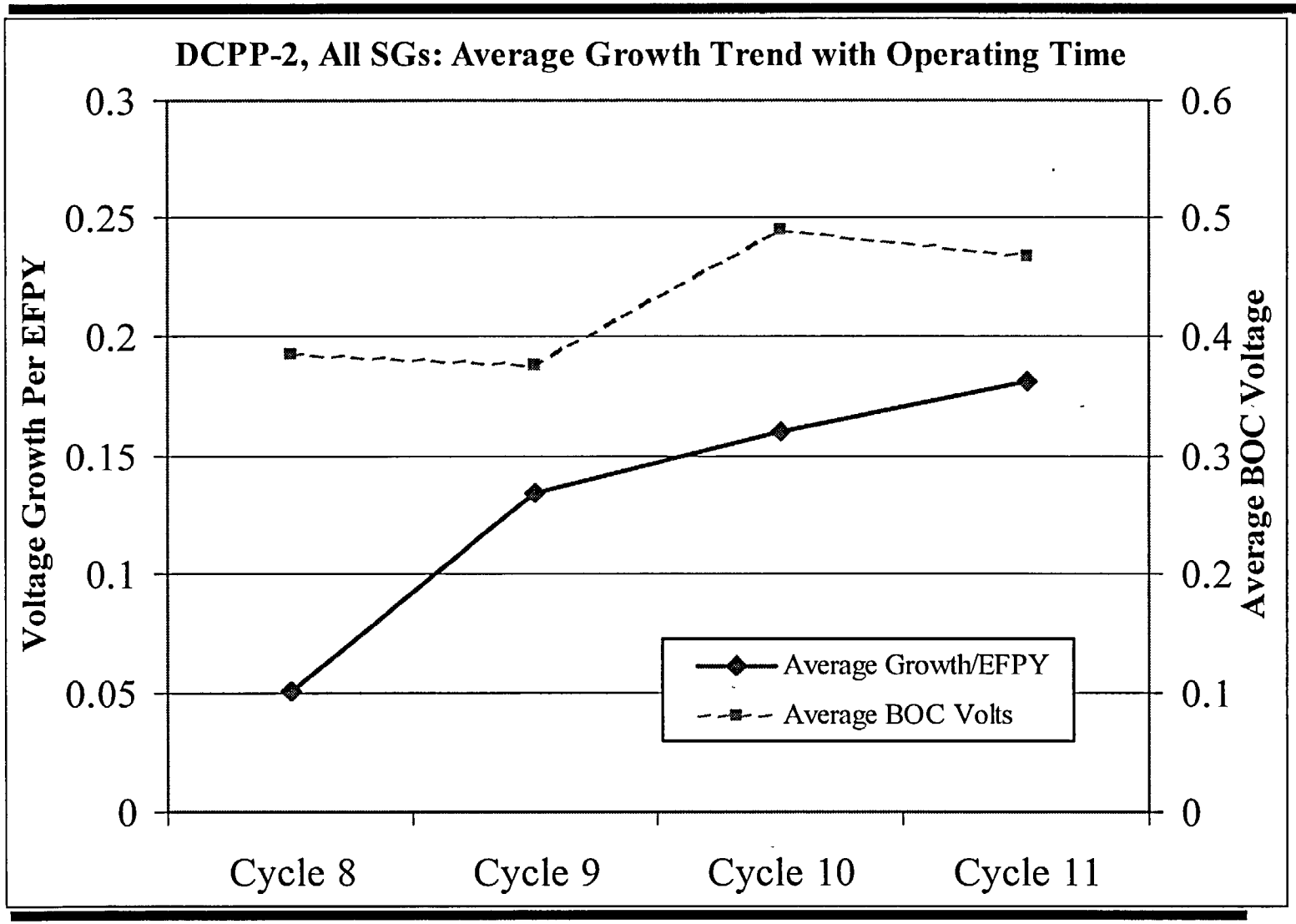
PG&E

Average Voltage Growth

- Average Voltage Growth
  - Modest increase in average growth for SG 2-4 over last three cycles is consistent with increased population above about 1 volt and very likely is not indicative of a large increase in depth growth rates
  - DCPP-2 average growth in SG 2-4 tends shows a modest increase of about 10% per cycle

PG&E

DCPP Average Growth Trend

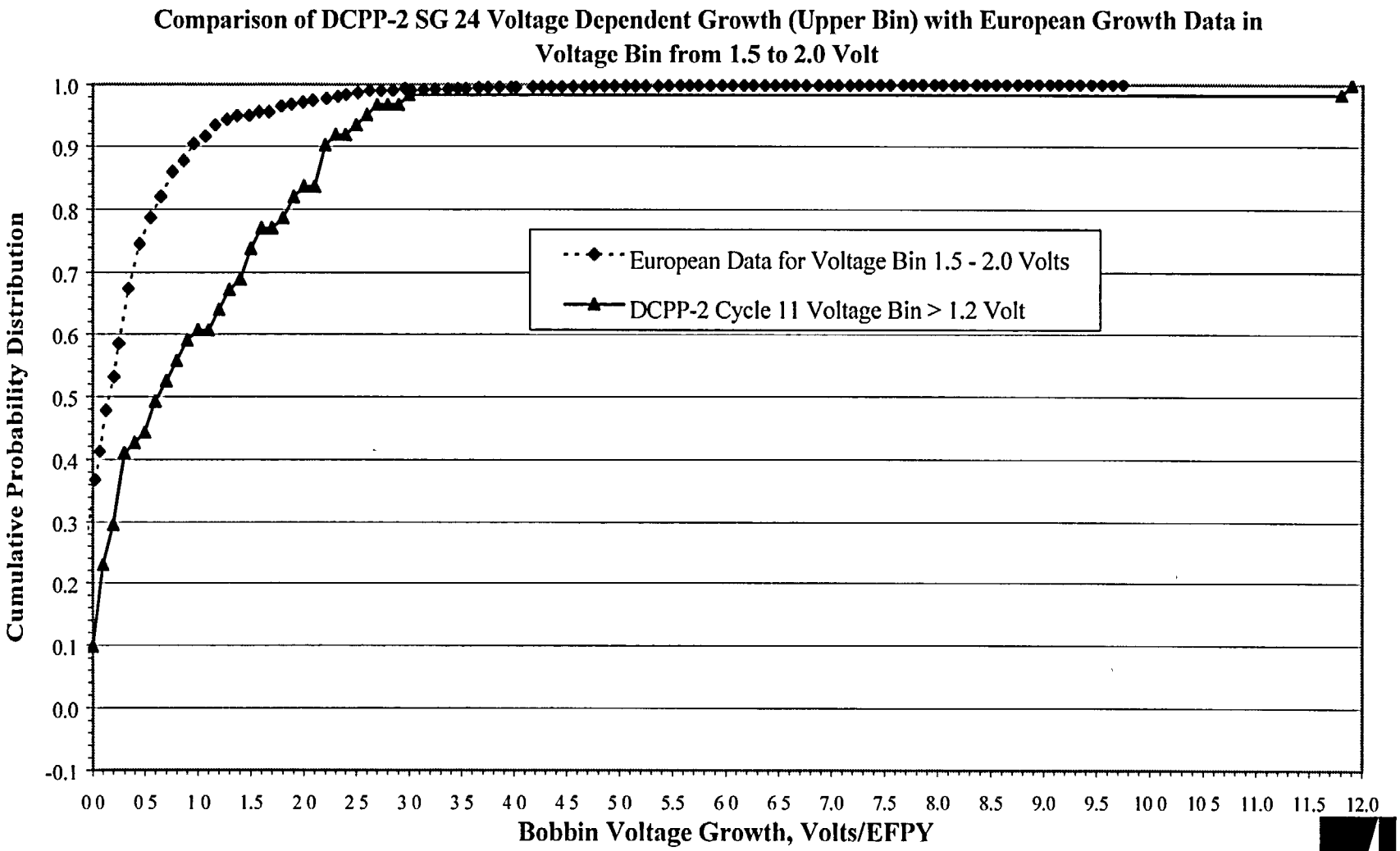


Comparison of DCPP-2 Cycle 11 Voltage Dependent Growth with European Data

- Comparison of DCPP-2 Cycle 11 Upper Bin (>1.2 volt) with European Data (1.5 to 2.0 volt bin)
  - DCPP-2 SG 2-4 upper bin voltage dependent growth distribution is significantly more conservative than European data based on a large population of indications that have been left in service for multiple cycles
  - The European data for a large population provides an expected trend for DCPP-2 growth data as the population of indications used to define the growth distribution increases

PG&E

DCPP SG 2-4 Voltage Dependent Growth (Upper Bin)

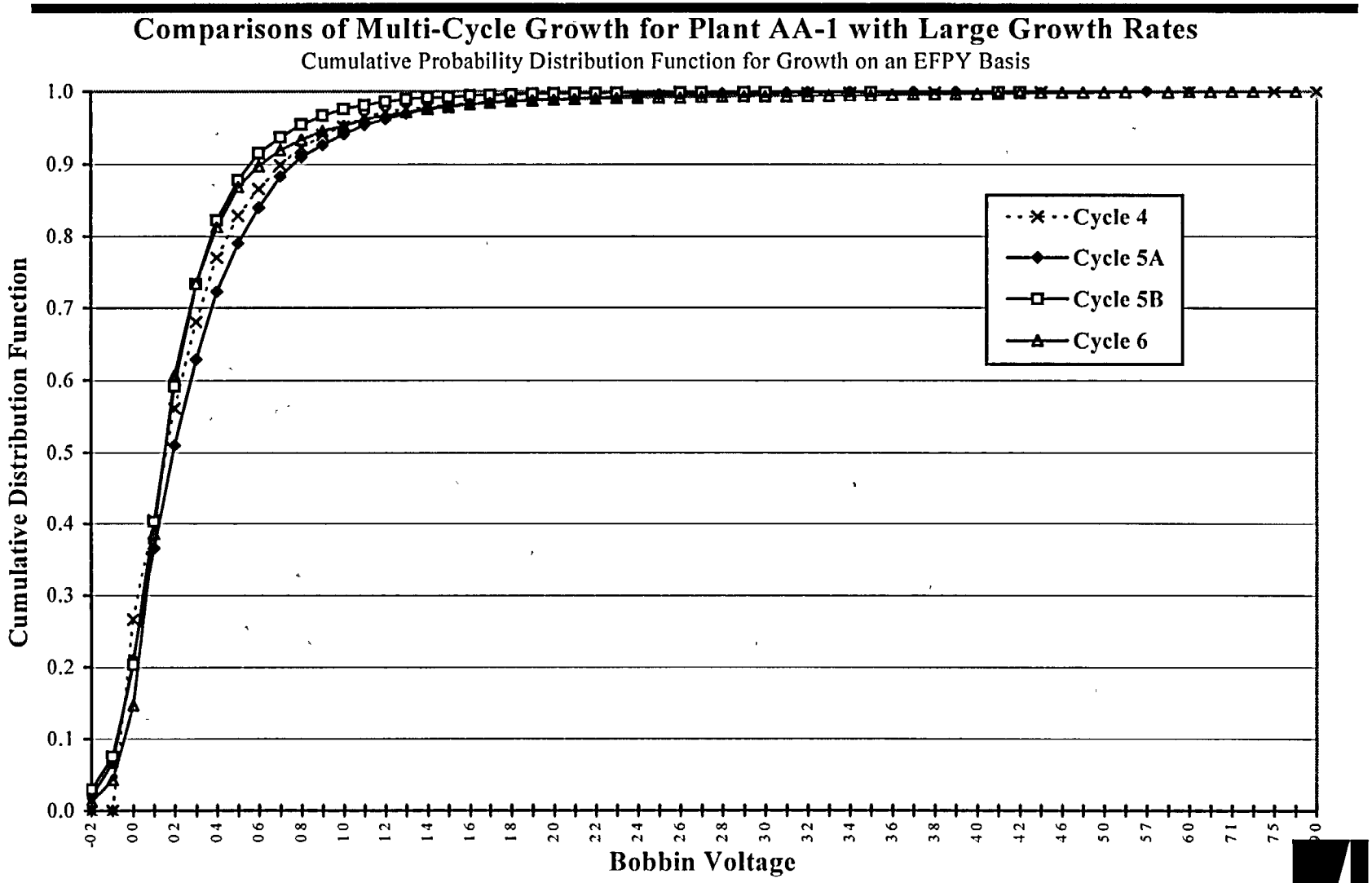


Comparisons of DCPP-2 Voltage Growth Rates with Plants with Large Growth

- Growth Distributions for Plants with Successive Cycles of Large Growth Rates
  - A few plants have operated for successive cycles following initial large voltage indications
  - Growth distributions do not show large differences between successive cycles (moderately increase or decrease between successive cycles)
- **Conclusion:** Growth distributions based on a large population do not show large changes between cycles as long as the growths are based on a significant number of indications

PG&E

Multi-Cycle Growth for Plant AA-1 with Large Growth Rates

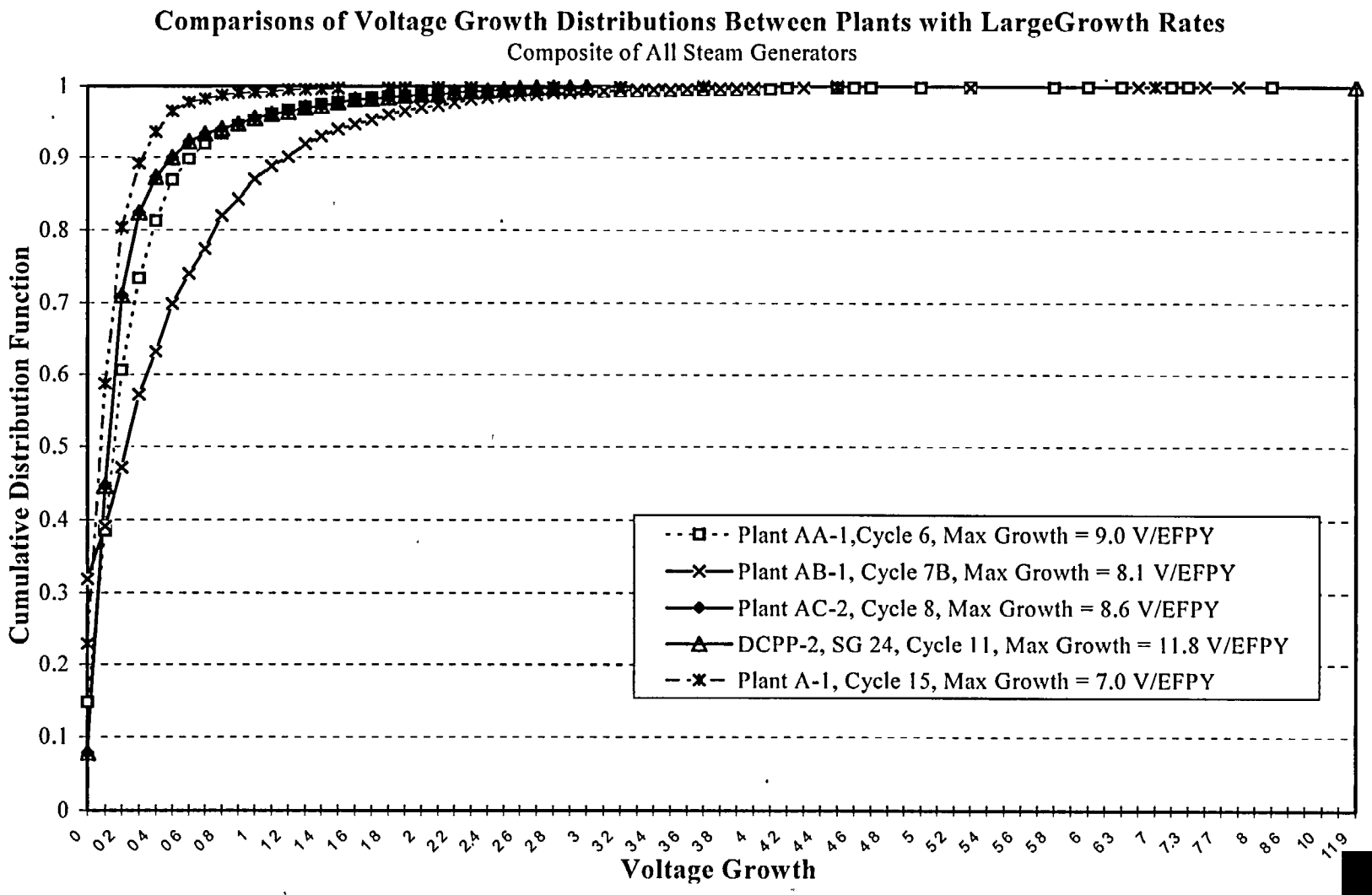


Comparisons of DCPP-2 Voltage Growth Rates with Plants with Large Growth Rates

- Voltage Independent Growth Rate Distributions
  - DCPP-2 SG 2-4 conservatively compared to composite sum of all SGs for 4 other plants rather than worst SG for other plants
  - DCPP-2 SG 2-4 growth distribution indicates larger growth than Plant A-1 composite growth distribution and comparable to Plant AC-2 distribution below about 2 volts
  - DCPP-2 SG 2-4 growth distribution slightly smaller growth than Plant AA-1 composite growth and significantly smaller growth than Plant AB-1 composite growth distribution
- **Conclusion**: DCPP-2 growth rates are less than found in other ARC plants with large growth rates

PG&E

Voltage Growth Distributions Between Plants with Large Growth Rates

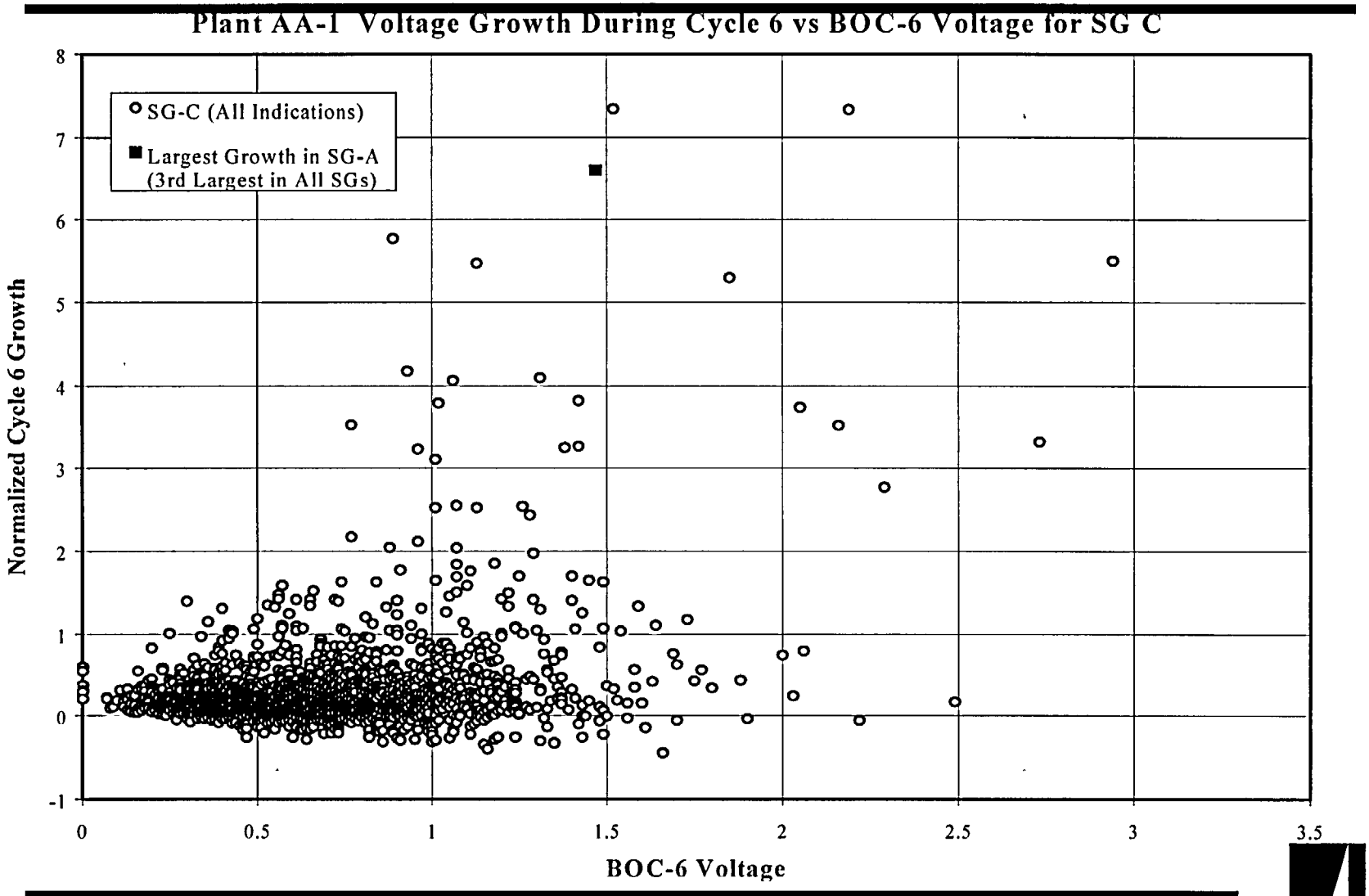


Voltage Dependent Growth Rate Comparisons with Plant AA-1

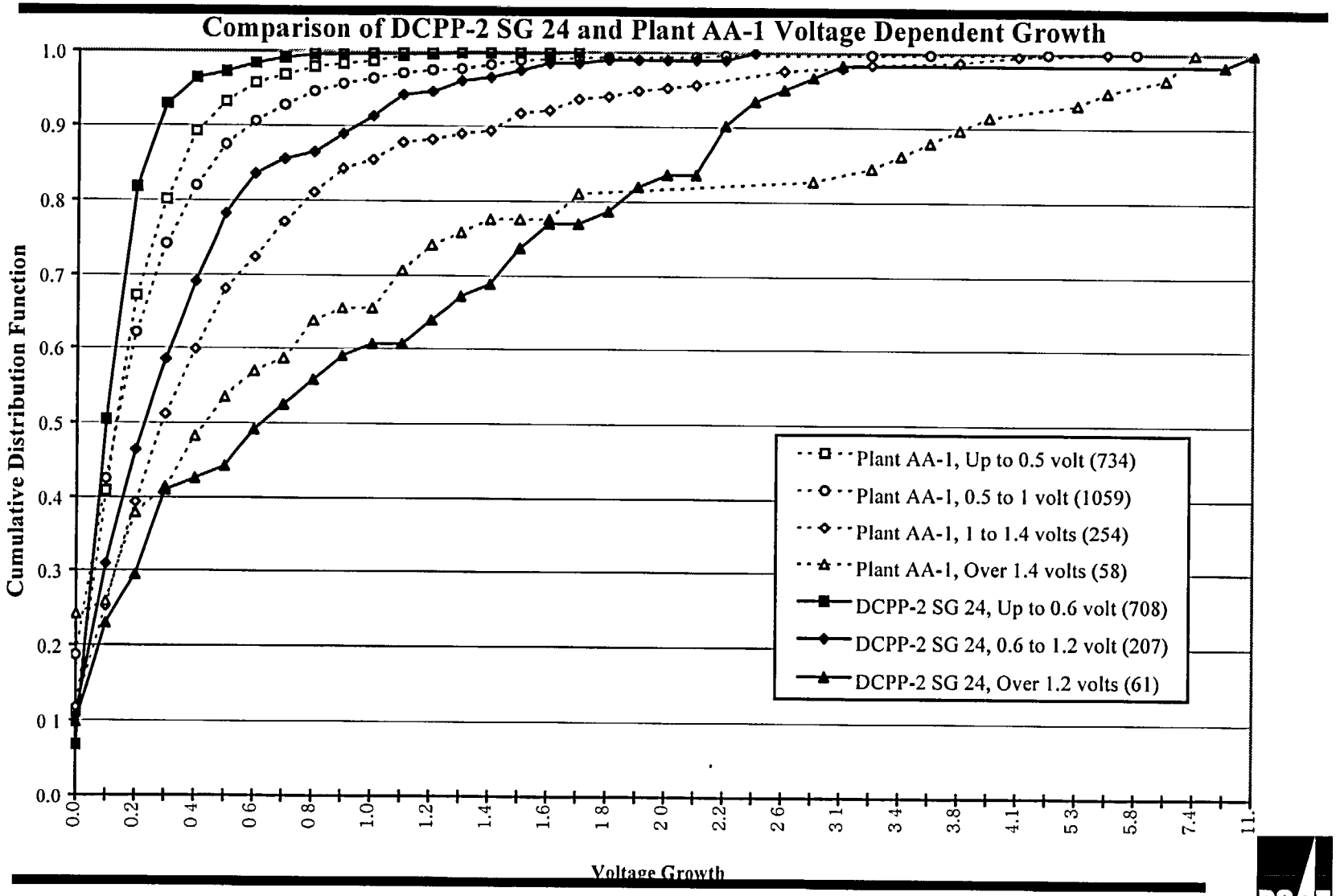
- Comparison of DCPP-2 SG 2-4 and Plant AA-1 SG C voltage dependent growth rates
  - DCPP-2 lowest bin shows lower growth rates than lowest bin of Plant AA-1 indicating a general expectation of lower growth rates for comparable BOC voltages
  - DCPP-2 middle bin (0.6 to 1.2 volts) lies almost midway between the 2nd bin (0.5 to 1.0 volt) and 3rd bin (1.0 to 1.45 volt) for Plant AA-1
  - DCPP-2 upper bin shows larger growth below about 2 volts but less about two volts due to the fact that DCPP-2 has only 1 indication above 3 volt growth

PG&E

Plant AA-1 Voltage Growth



DCPP SG 2-4 and Plant AA-1 Voltage Dependent Growth



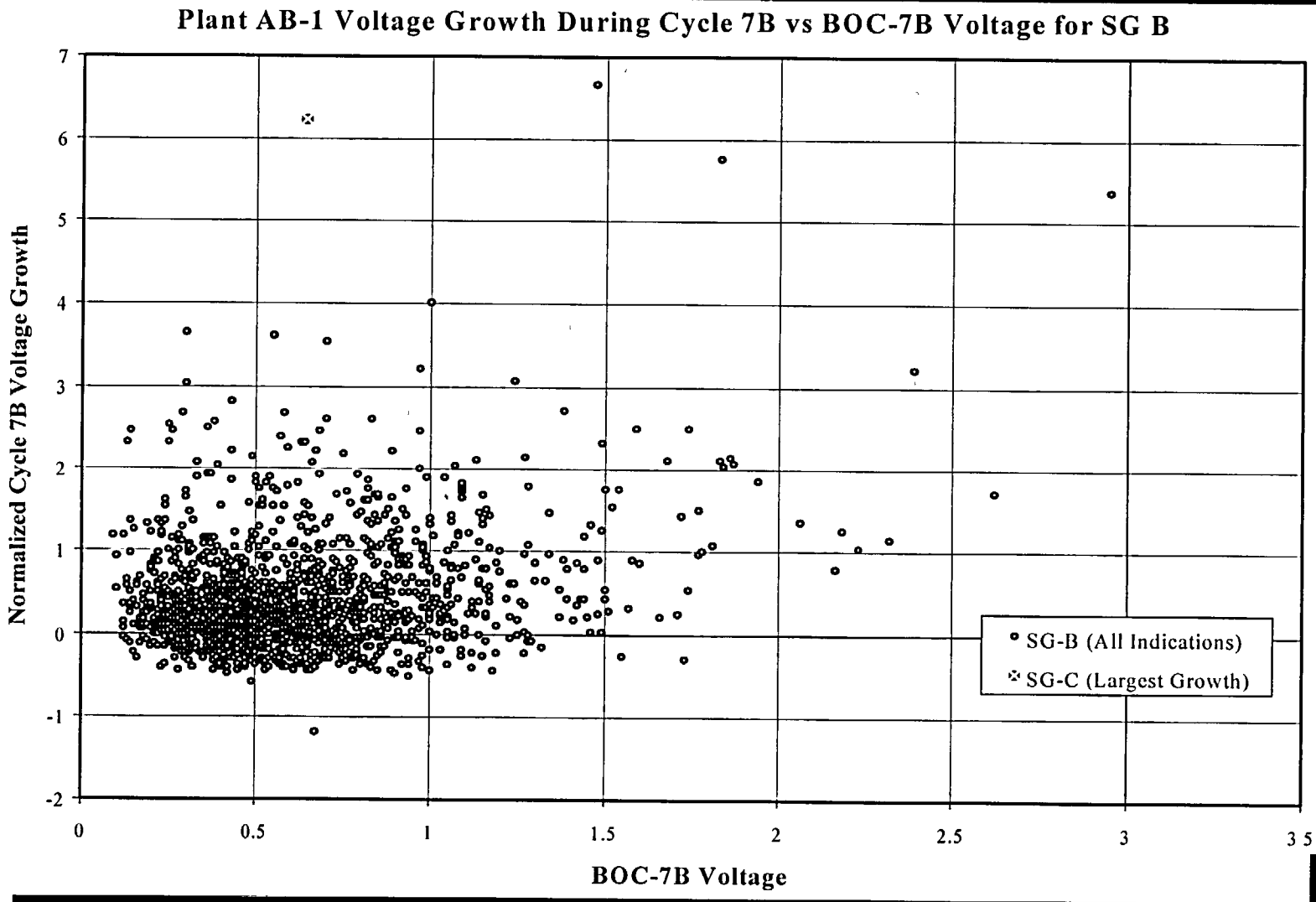
PG&E

Voltage Dependent Growth Rate Comparisons with Plant AB-1

- Comparison of DCPP-2 SG 2-4 and Plant AB-1 SG C voltage dependent growth rate
  - DCPP-2 lower two bins spanning up to 1.2 volts show lower growth than the lower two bins for Plant AB-1 due to the larger number of growth rates above 1 volt in Plant AB-1 compared to DCPP-2
  - DCPP-2 upper bin also shows lower growth than the upper bin for Plant AB-1 due to the larger fraction of growth rates above 1 volt and above 3 volts in Plant AB-1 compared to DCPP-2

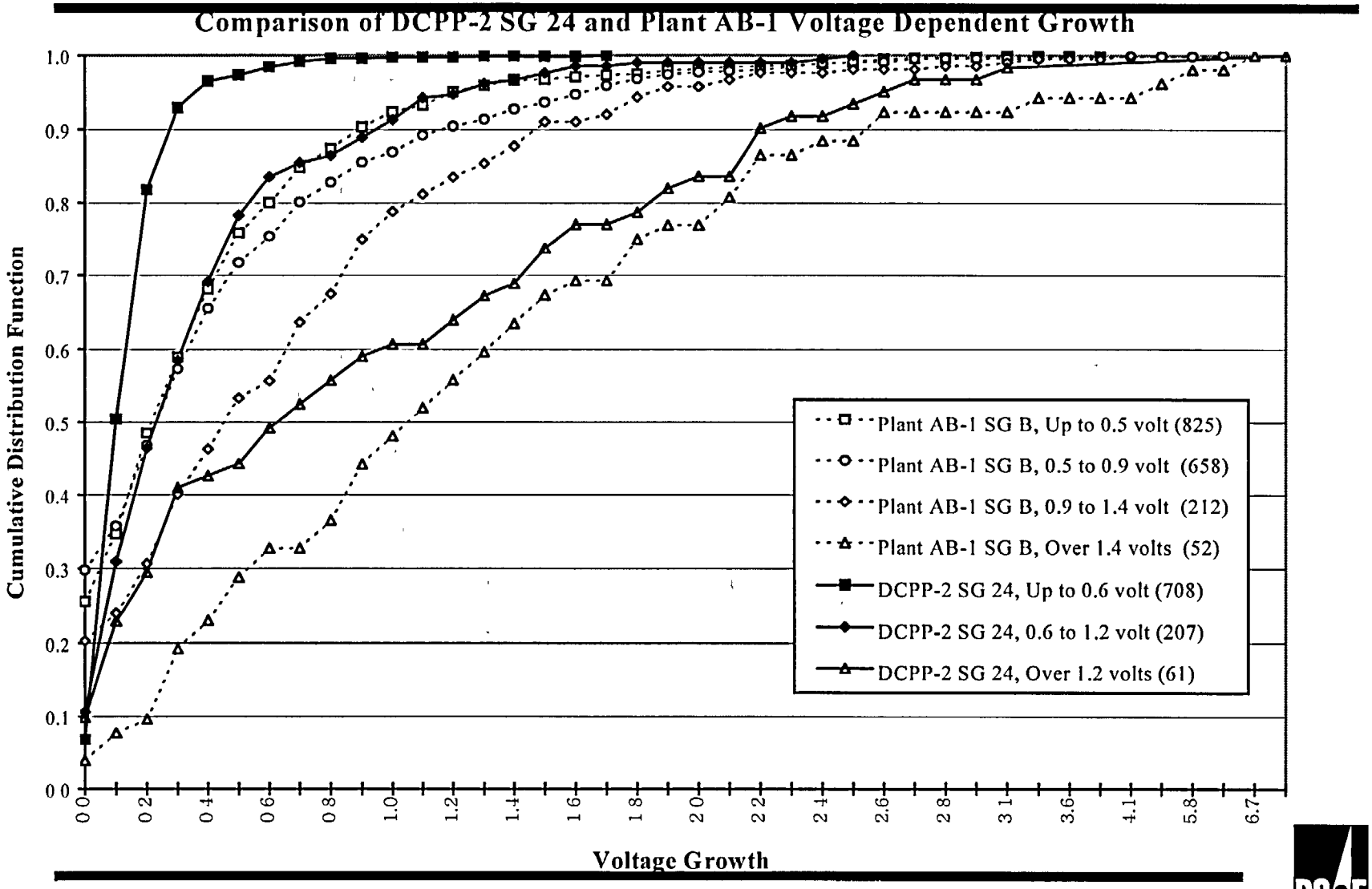
PG&E

Plant AB-1 Voltage Growth



PG&E

DCPP SG 2-4 and Plant AB-1 Voltage Dependent Growth



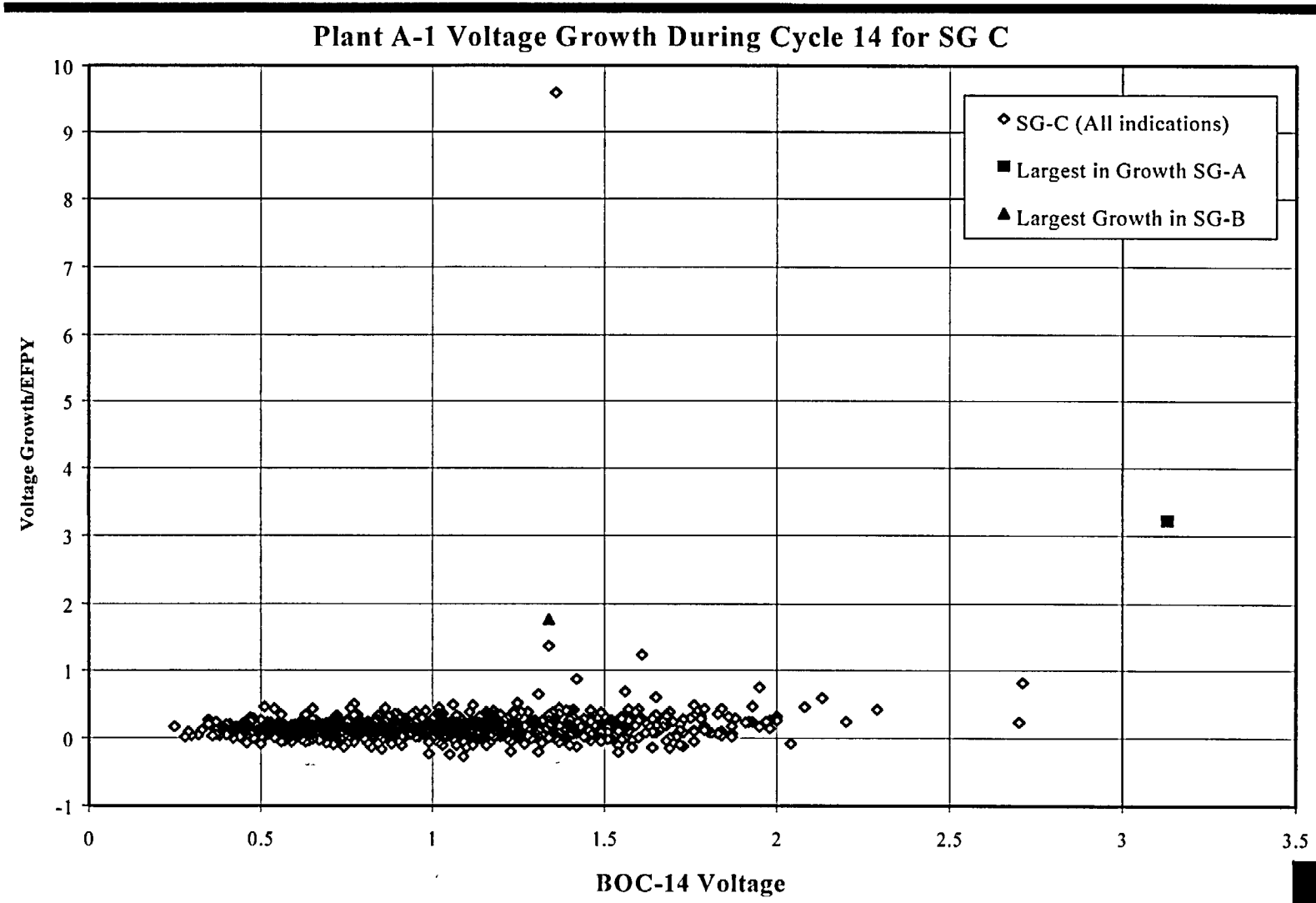
PG&E

Voltage Growth Rates for Plants A-1 and AC-2

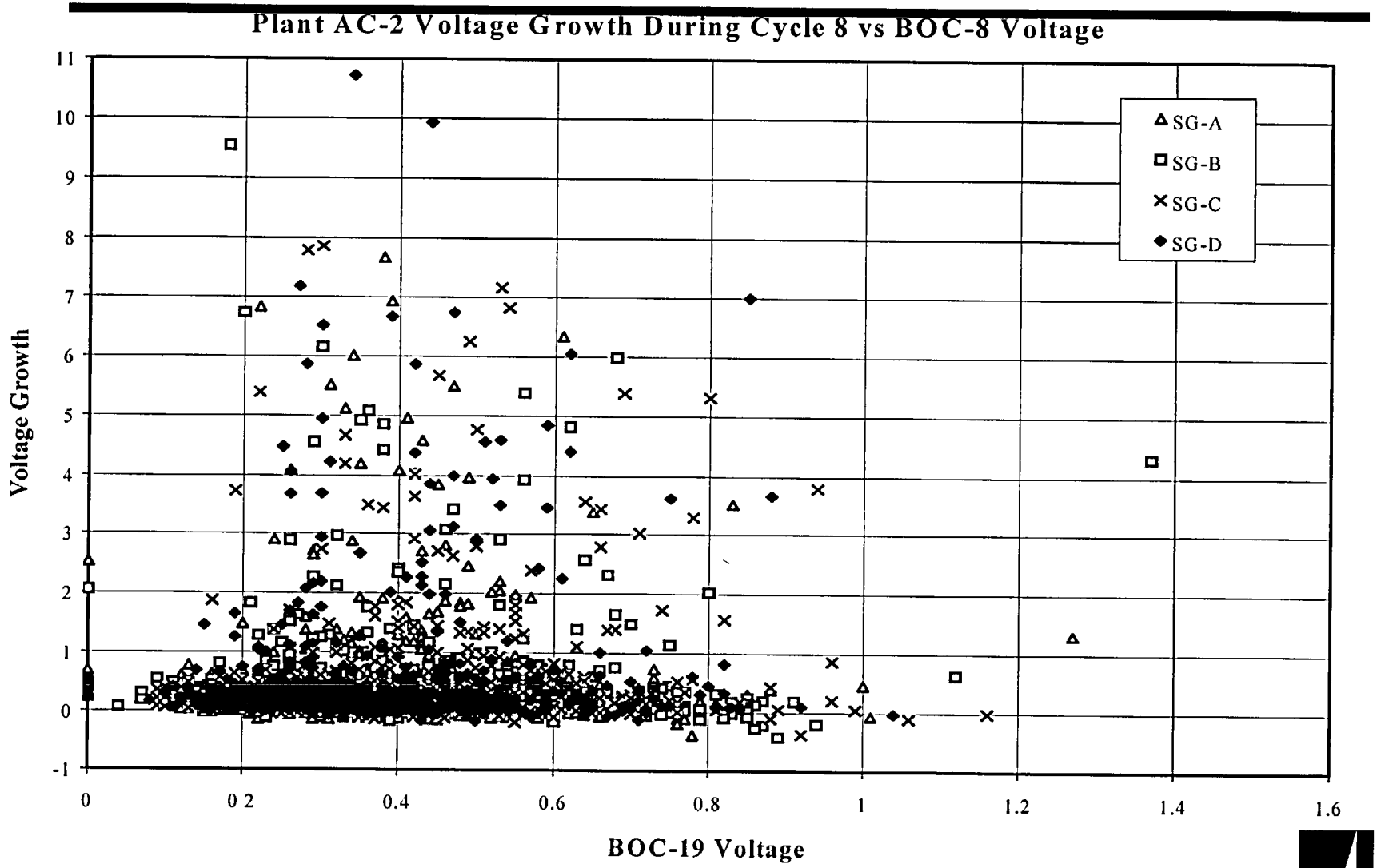
- Plant A-1 SG C voltage growth
  - The Plant A-1 data show a single large growth rate but no significant trend toward BOC voltage dependence
  - Large single growth similar to DCPP-1 R44C45
- Plant AC-2 SG C growth rate
  - The Plant AC-2 growth data show large growth rates even at low voltages and do not show a significant dependence on BOC volts
  - Large growth enhanced by high temperatures (620°F) and cannot be compared with DCPP-2 voltage growth
- **Conclusion:** The DCPP-2 SG 2-4 voltage dependent growths show higher frequency for moderate growths (<3 volts/EFPY) at higher voltages (> 1.2 volt) than all but one of the four plants found with large EOC indications

PG&E

Plant A-1 Voltage Growth



Plant AC-2 Voltage Growth



PG&E

Bobbin Voltage Growth Dependence on BOC +Point Volts

- Reason for assessing dependence of bobbin voltage growth on BOC +Point volts
  - At 2R10, the R44C45 indication had a +Point voltage based on line by line sizing of 2.97 volts and a bobbin voltage of 2.0 volts for a +Point to bobbin voltage ratio of 1.5.
  - +Point to bobbin voltage ratios above unity are infrequent for ODSCC indications at TSP intersections and likely indicate a dominant single crack at the TSP intersection
  - R44C45 also had the largest bobbin voltage growth

PG&E

Bobbin Voltage Growth Dependence on BOC +Point Volts

- Potential factor for large bobbin growth of R44C45
  - The high BOC +Point voltage is indicative of a potential through-wall indication
  - A high +Point to bobbin voltage ratio coupled with a significantly high +Point voltage (i.e., > 1.5 to 2.0 volts) may imply an indication that could have a large voltage growth in the next cycle

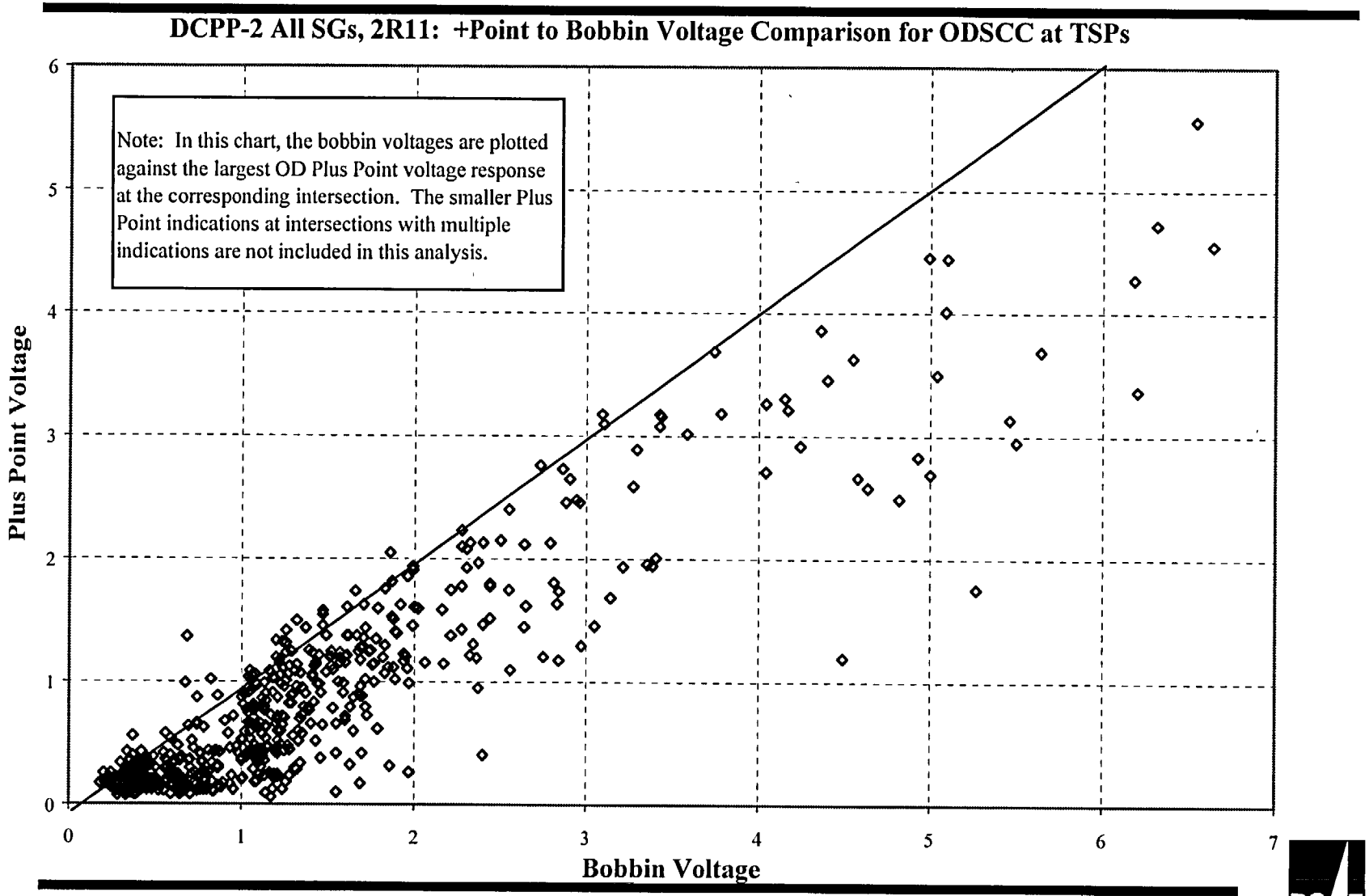
PG&E

Assessment of Bobbin Voltage Growth Dependence on BOC +Point Volts

- The 2R11 data do not show any indications above a +Point voltage of 1.5 volts with +Point to bobbin coil ratios > 1.10 (indications plugged based on preventive repair limit for Cycle 12)
  - Data includes 100% +Point inspection of TSP bobbin indications above 1 volt and a sample of indications below 1 volt
  - A few indications below 1 bobbin volt show higher +Point to bobbin voltage ratios
    - However, the 1R10 data below +Point voltages of about 1.5 do not show any trend of increasing bobbin voltage growth with BOC +Point volts

PG&E

DCPP +Point to Bobbin Voltage Comparison for ODSCC at TSPs



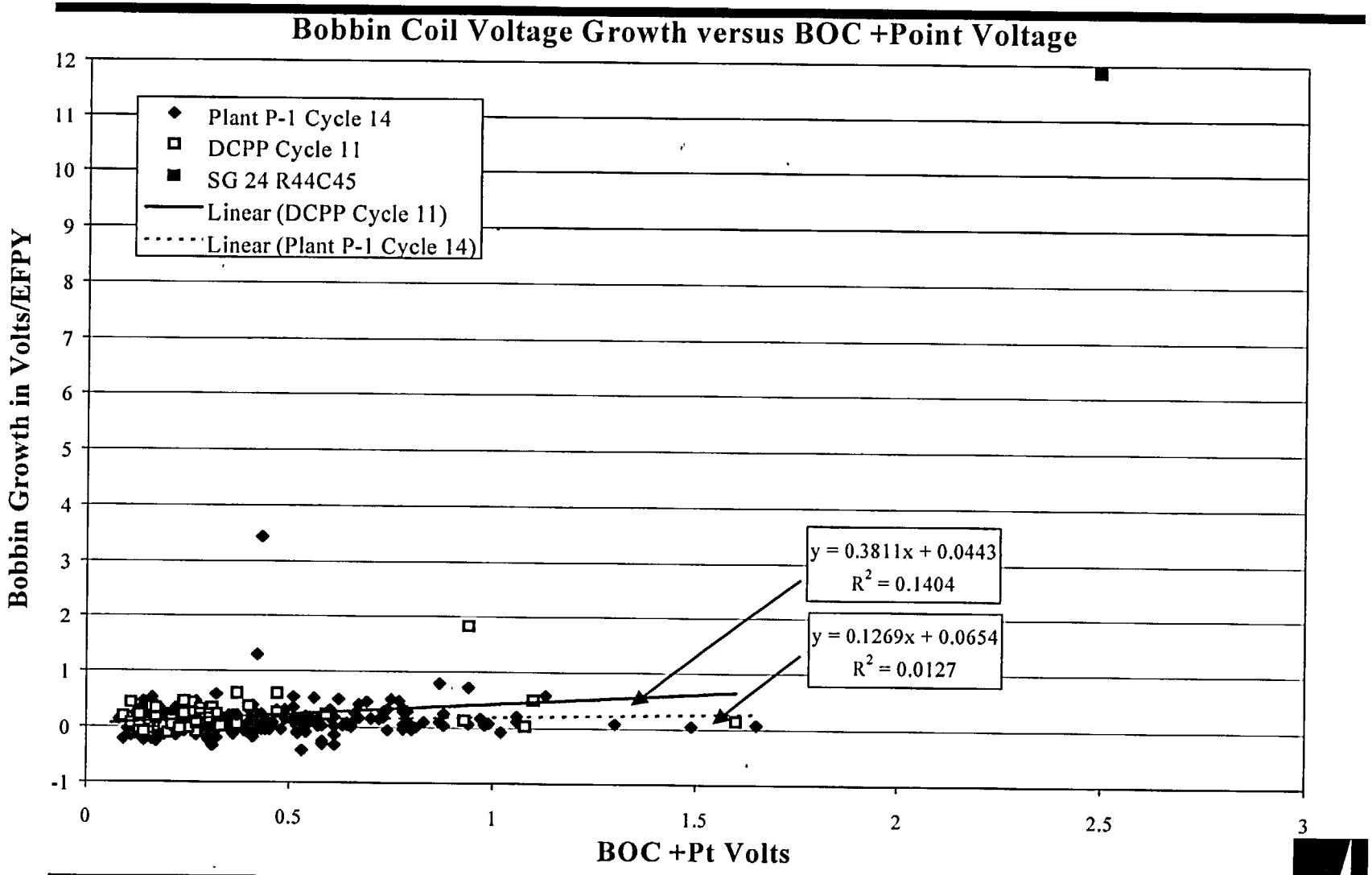
PG&E

Assessment of Voltage Growth Dependence on BOC +Point Volts

- Assessed Cycle 11 bobbin coil voltage growth relative to 2R10 (BOC-11) +Point voltage as a potential trend for large bobbin growth
  - Data evaluated for DCPP-2 Cycle 11 and another plant with 7/8" tubing applying the ARC
  - With the exception of R44C45, the available data are limited to BOC +Point voltages < 1.5 volts
  - No trend is found for bobbin voltage growth to increase significantly with BOC +Point volts up to the limit of the available data (1.2 to 1.5 +Point volts

PG&E

Bobbin Coil Voltage Growth vs. BOC +Point Voltage



Preliminary Assessment of Largest +Point Voltage Indications Below 1.2 Bobbin Volts

- Selection of indications for evaluation
  - Largest 20 +Point voltage indications over all SGs
  - Largest 5 +Point voltage indications in each SG
- Assessment
  - Amplitude sizing applied to indications
  - CM and OA analyses performed per indication
    - Analysis methods same as applied for PWSCC ARC
    - DCPP-2 depth growth rate distribution applied
    - NDE Uncertainties: Standard deviation of 7% on depth, 0.065" on length

PG&E

Preliminary Assessment of Largest Indication

- Limiting indication
  - SG 2-4, R15C45-2H, Max +Point volts = 1.54
  - Max depth: Amplitude sizing = 89%,
    Phase sizing = 63%
  - Length: Total NDE = 0.65", burst effective = 0.47"
  - Average Depth (amplitude sizing): Total NDE = 71.2%, burst effective = 81.4%
    - "Bath tub" flaw shape (most limiting)
  - Burst pressures and probability of burst
    - $BP_{CM,\ nom}$ = 4.318 ksi
    - $BP_{CM,\ 95\%}$ = 3.463 ksi, POB = 3.1E-05
    - $BP_{OA,\ 95\%}$ = 3.005 ksi, POB = 1.07E-03

PG&E

Preliminary Assessment of Balance of Largest +Point Indications

- Maximum +Point volts < 1.4 volt
- Maximum depths ≤ 87%
- Maximum NDE length < 0.5"
- $BP_{CM, 95\%}$ = 4.4 to 5.4 ksi, POB = <E-05 (all indications)
- $BP_{OA, 95\%}$ = 3.8 to 4.8 ksi, POB = ≤1.1E-05
- Combined burst probability for 28 indications <3E-04
- Conclusions
  - All +Point indications below 1.2 bobbin volts satisfy structural integrity at EOC-12
  - No very large bobbin voltage growth would be expected for these indications
    - SG 2-4 R15C45 preventively plugged for further confidence

PG&E

Assessment of Voltage Growth Dependence on BOC +Point Volts

- BOC +Point voltages up to about 1.5 volts do not appear to be a potential indicator for high bobbin voltage growth
- Indications with +Point volts < 1.5 would likely have maximum depths < 85% (based on correlation with destructive exam data), and growth to a long through-wall length for a large bobbin voltage growth is unlikely
  - Long throughwall would require a near uniform depth flaw ("bath tub" flaw) which has a low likelihood of occurrence
- No conclusion can be drawn for BOC +Point voltages > 1.5 volts due to the lack of data for an assessment

PG&E

Observations on DCPP-2 Voltage Growth Rates

- SG 2-4 growth in bin up to 0.6 volt did not change between Cycles 10 and 11
- SG 2-4 growth in bin above 1.2 volt (excluding R44C45) is essentially the same for Cycles 10 and Cycle 11
- SG 2-4 growth in bin between 0.6 volt and 1.2 volt shows a small increase from Cycle 10 to Cycle 11
- SG 2-4 growth in the upper bin (> 1.2 volt) is very conservative compared to the European experience based on a large population of indications
- The DCPP-2 growth distributions show smaller growth rates than found in other domestic plants having high growth rates
- The DCPP-2 growth in depth for Cycle 11 shows a lower growth rate distribution than found in other plants tending toward large ODSCC growth rates
- The average growth rates in DCPP-2 increased by about 10% per cycle over the last two cycles

PG&E

Projections of DCPP-2 Voltage Growth Rates for Cycle 12

- Recommendations for Cycle 12 Growth Distributions
  - Maximum voltage growth rate for distributions
    - Retain R44C45 growth rate as the maximum growth rate in the upper voltage bin (> 1.2 volt)
    - R44C45 growth of 11.8 volts/EFPY is the largest growth seen domestically and internationally
  - Voltage bin ≤ 0.6 volt
    - Apply Cycle 11 growth distribution for Cycle 12
    - Voltage growth in Cycle 11 did not increase relative to Cycle 10 in this bin

PG&E

Projections of DCPP-2 Voltage Growth Rates for Cycle 12

- Recommendations for Cycle 12 Growth Distributions (cont.)
  - Voltage bin 0.6 volt to 1.2 volt
    - Increase growth rate by 10% over the entire voltage range
    - Only voltage range to show increased voltage growth for Cycle 11 compared to Cycle 10
    - Fraction of indications with growth rates up to about 2.5 volt/EFPY increased in Cycle 11
    - Growth increase likely due to a significant increase in BOC 11 population in this bin compared to BOC 10

PG&E

Projections of DCPP-2 Voltage Growth Rates for Cycle 12

- Voltage bin > 1.2 volt
  - Combine growth data in this bin from Cycles 10 and 11 to define Cycle 12 growth distribution
  - Growth rates in this bin have been essentially the same for the last two cycles with the exception of the R44C45 indication with the maximum growth rate for both cycles bounded by 3 volts per EFPY
  - A large growth (R44C45) rate occurred only once in the last two cycles so the appropriate fraction for the large growth rate is one divided by the sum of the indications in the two growth distributions
  - The preventive plugging being applied for Cycle 12 reduces the likelihood of a large growth rate comparable to R44C45 to negligible levels

PG&E

Modified POD for R44C45 – 2H

- Largest flaw found in 2R11 or other ARC inspection
- Large voltage growth due to "normal" physical growth
- Flaw was not missed – purposely left in service under ARC > 2 volt limit
- 0.6 POD returns 21.5 volt flaw to service 2 out of 3 trials during Monte Carlo simulation – failing POB criteria
- Substantial POD data show the POD nears 1 at about 3-4 volts (largest known missed flaw 3.2 volts)
- PG&E LAR will request approval of 1.0 POD for this flaw by 3/7/03 to support Mode 4 entry

PG&E

Startup Calculations and Assumptions

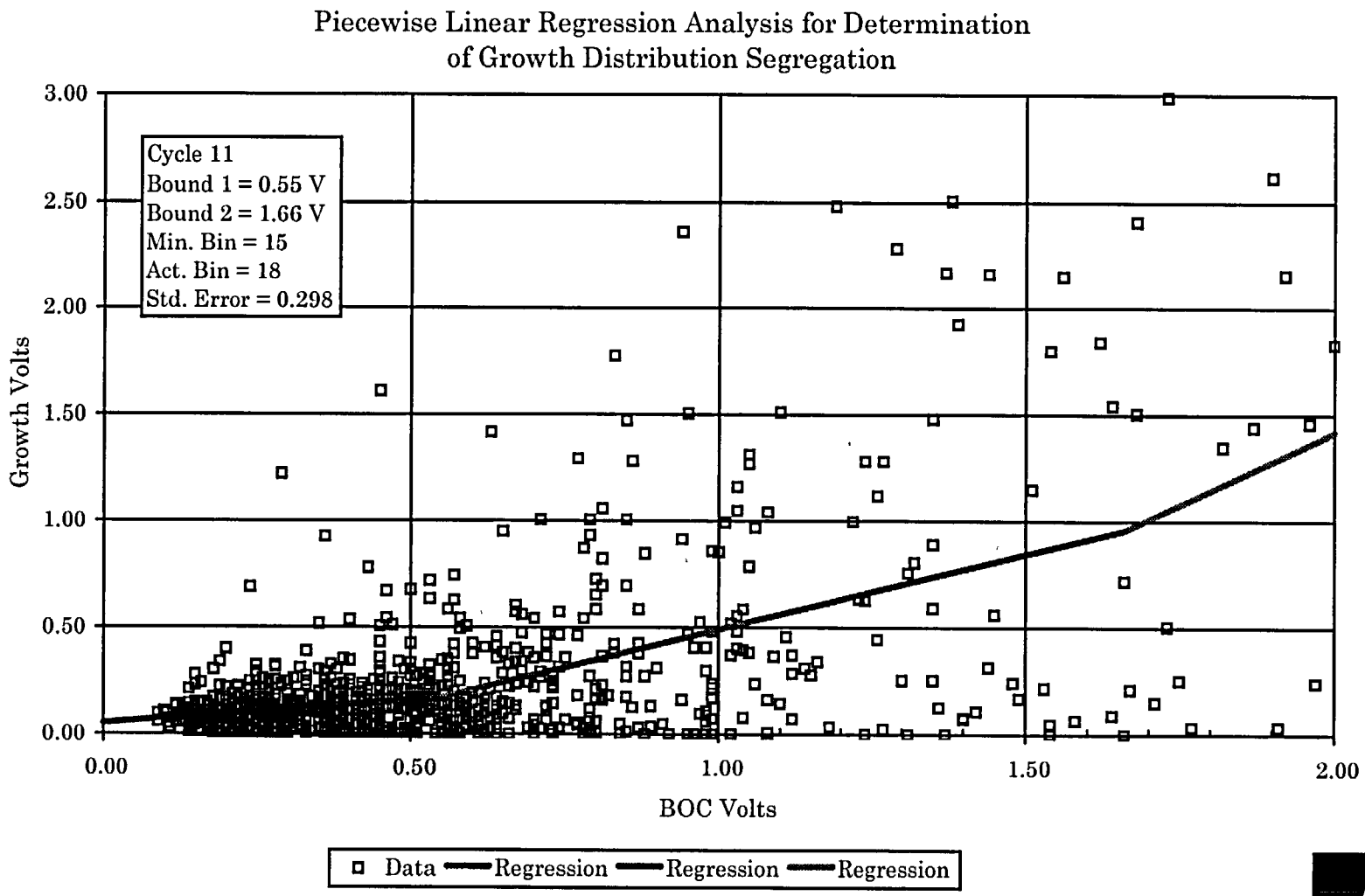
- Binning strategy
- VDG for SG 2-4
- VDG for other SGs (use 2-4 growth)
- 120 day predictions
- POPCD and full cycle
- Benchmarking

PG&E

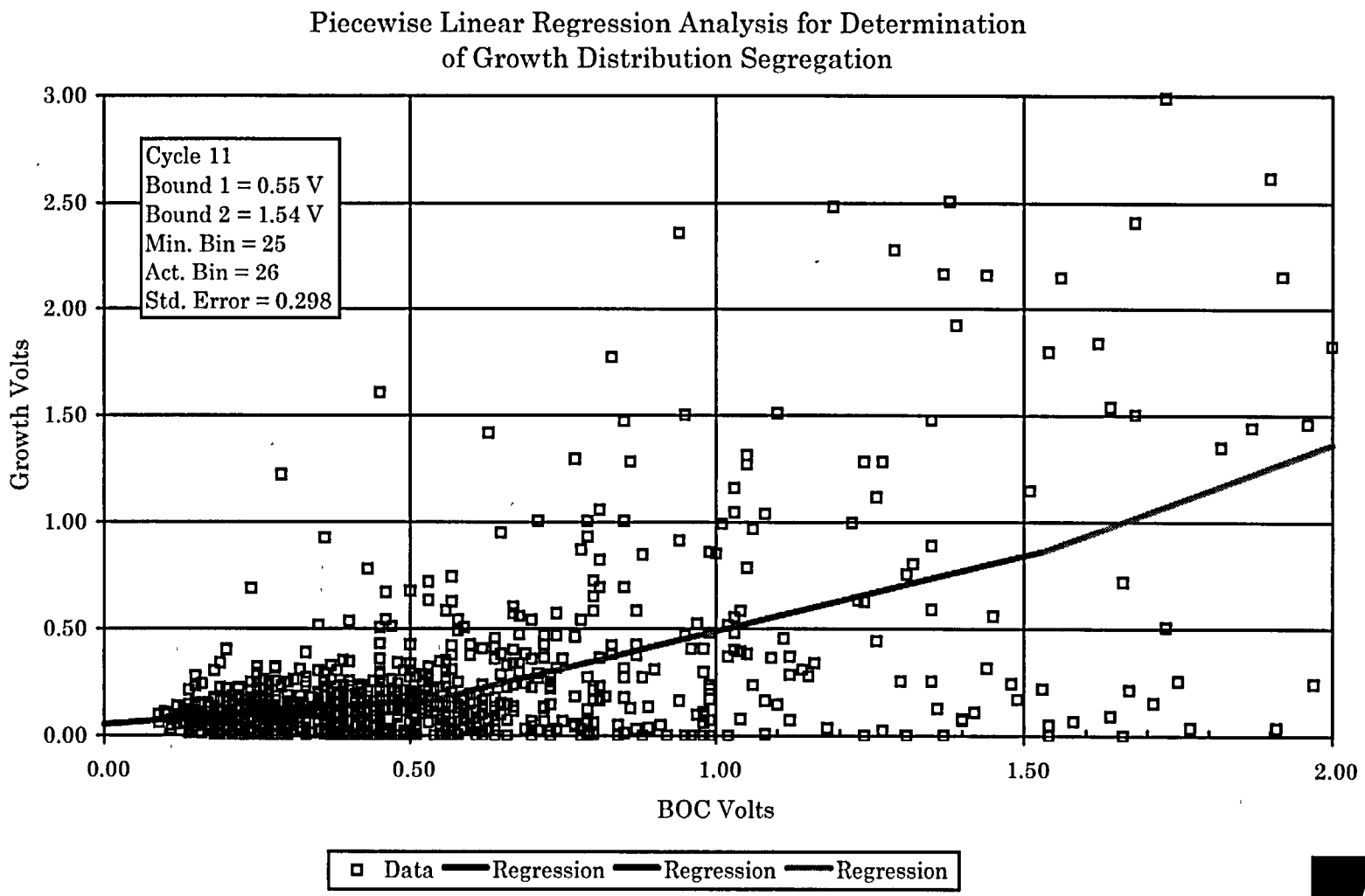
Bin Sizes for VDG

- Evaluation to assess appropriate segregation values (SVs) for Voltage Dependent Growth analysis.
  - Growth following one relation to some voltage and then another relation beyond would be Bi-Linear.
  - Extend to Tri-Linear and Quad-Linear considerations.
- Solve for SV values that minimize the standard error, i.e., maximize the R^2, of piecewise linear regressions.
  - Used only to identify voltage locations where the data are indicating a change in relation.
    - Not to predict voltage growth values.
  - Assess sensitivity to limit the minimum number of data in the uppermost voltage bin.

Cycle 11 Tri-linear Regression



Cycle 11, N_{Min}=25

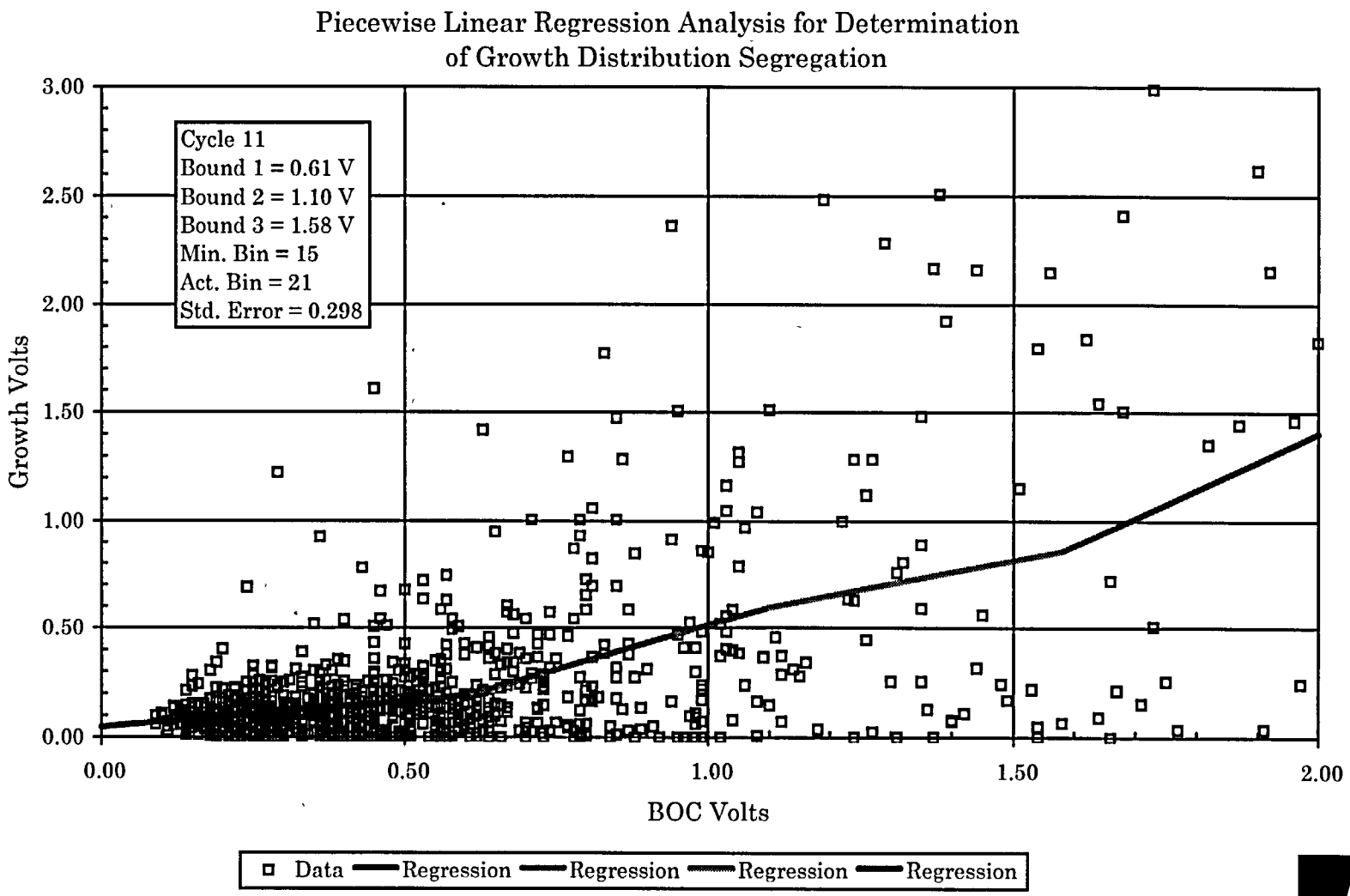


Cycle 11 Results Analysis

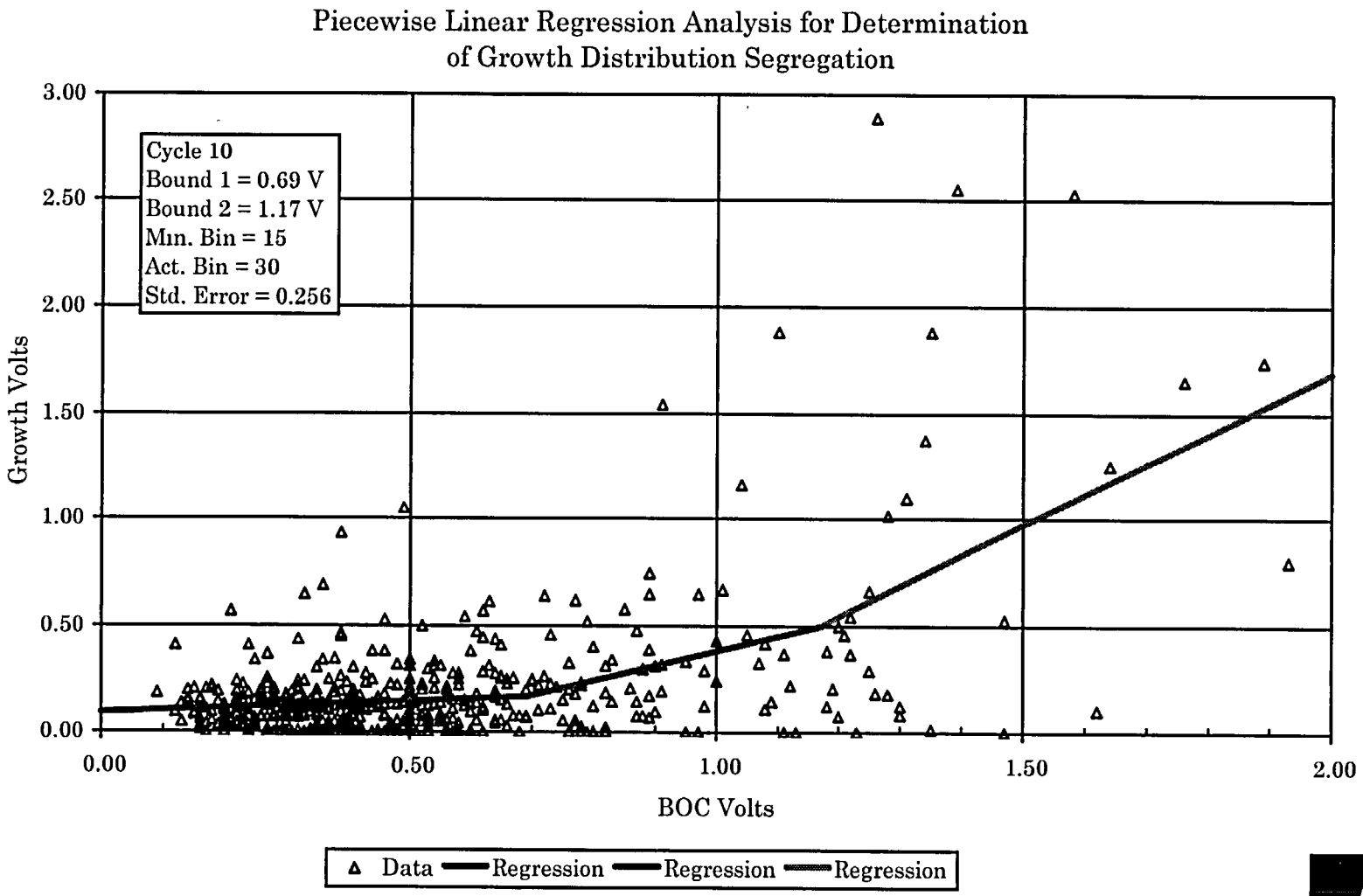
- The Tri-Linear regression performs as well as the Quad-Linear regression.
  - The standard error of regression and hence the R^2 values are the same.
  - The increase in complexity of the analysis does not improve the fit, therefore, the increase in complexity is not warranted.
- The Tri-Linear regression is sufficient to identify locations where the data are indicating a different dependent behavior.
  - Evidenced by a different slope behavior in the regression analysis.

PG&E

Quad-Linear Regression



Cycle 10 Tri-Linear

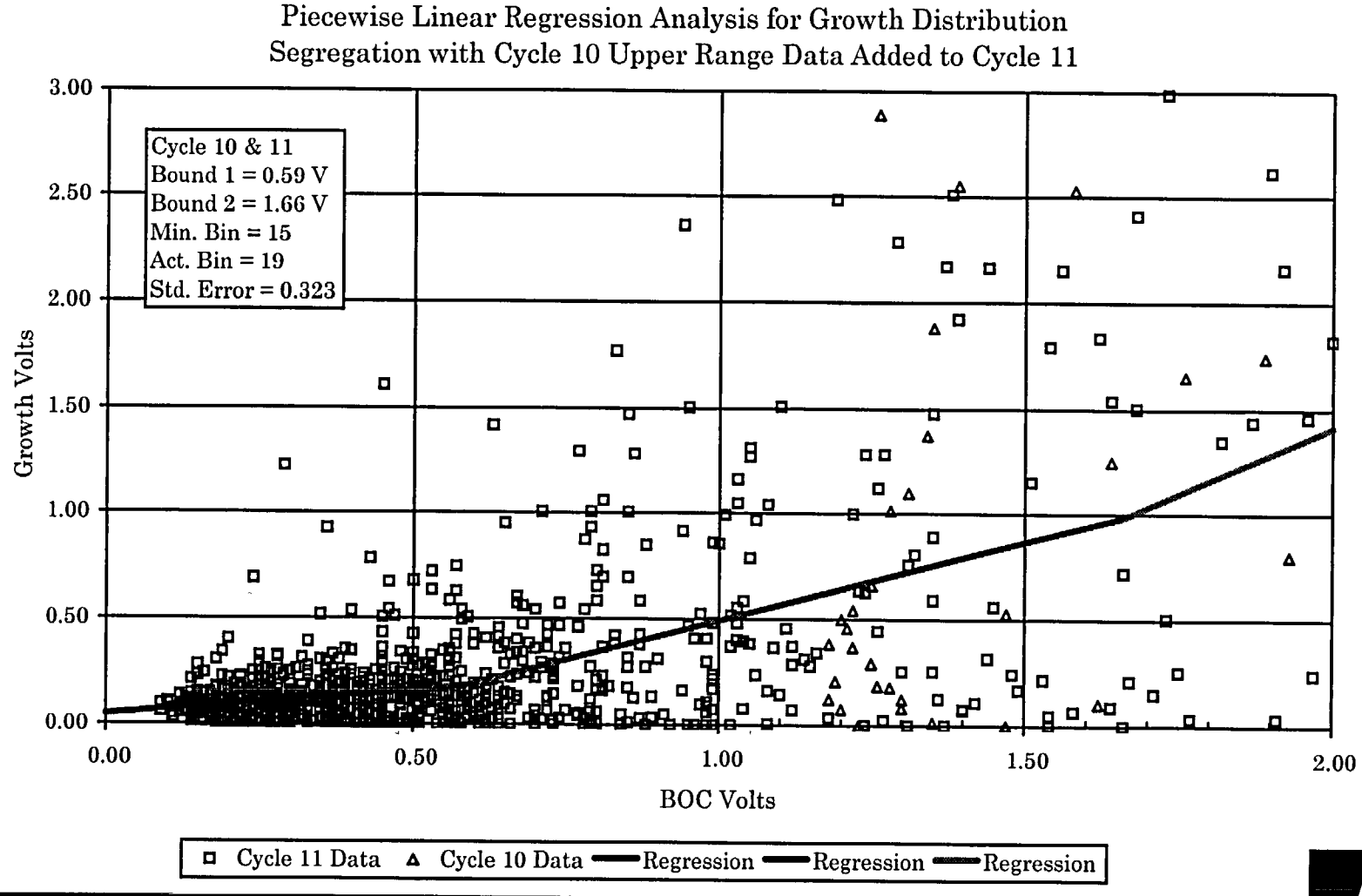


Analysis of Cycle 10 Results

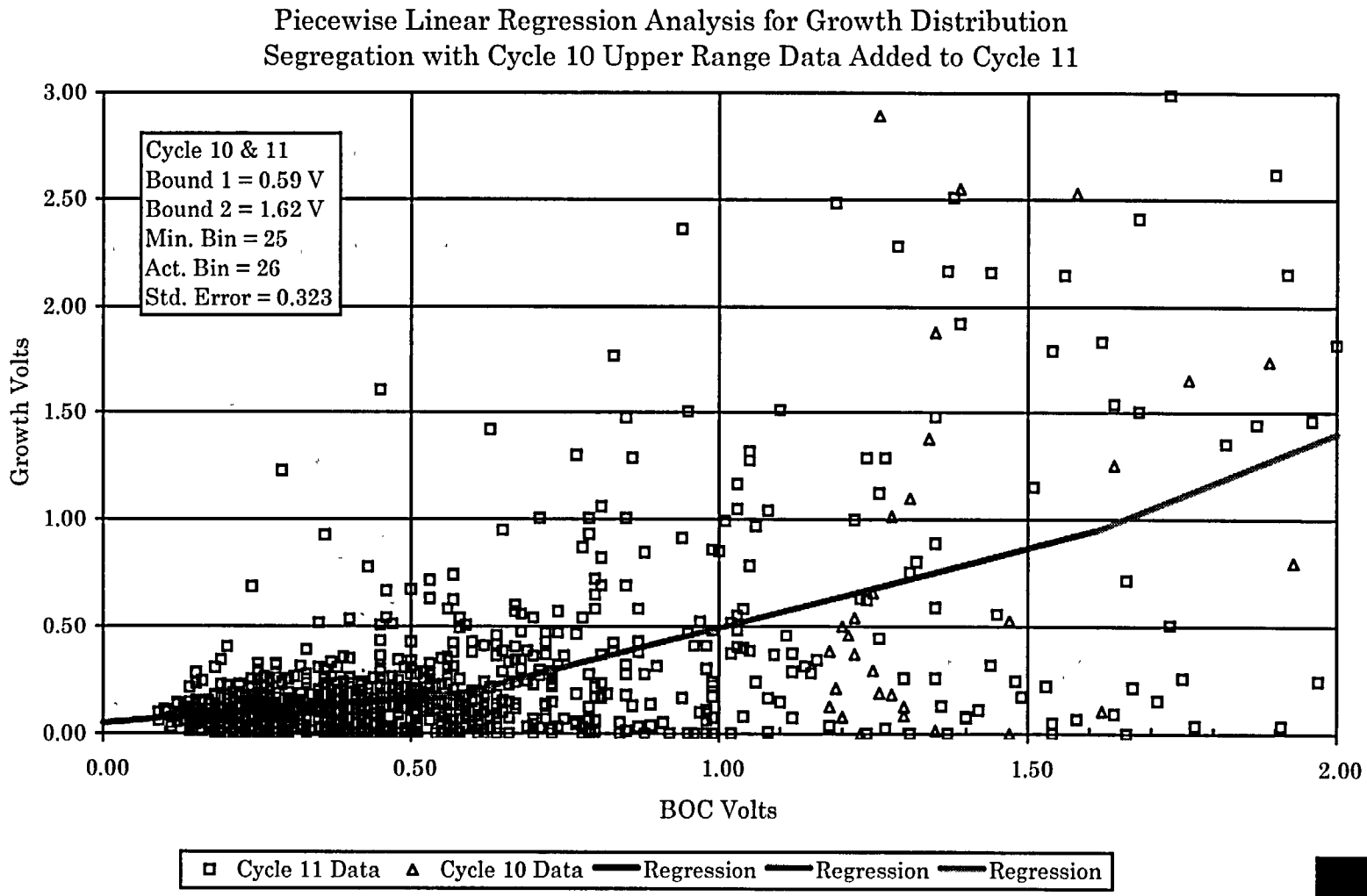
- Setting the minimum number of data in the upper bin to 15 results in an upper bin size of 31.
  - The analysis with an upper bin size of 25 would not change the result.
- The break or transition point for the regression was at 1.17 Volts.
  - All data greater than or equal to 1.17 Volts were added to the Cycle 11 data for analysis.

PG&E

Cycle 10 & 11 Tri-Linear



Cycle 10 & 11, N_{Min}=25



PG&E

Discussion of Results

- The N=25 case actually has a slightly higher error standard deviation.
- The actual value of 26 results because of the 25th and 26th voltages are the same.
  - Thus, the actual is also 25.
- Setting N=25 manually forces the segregation voltage value lower.
  - The solution cannot converge to a higher voltage value to minimize the error.
- Conclusion — Setting N=25 is inappropriate relative to minimizing the standard error.

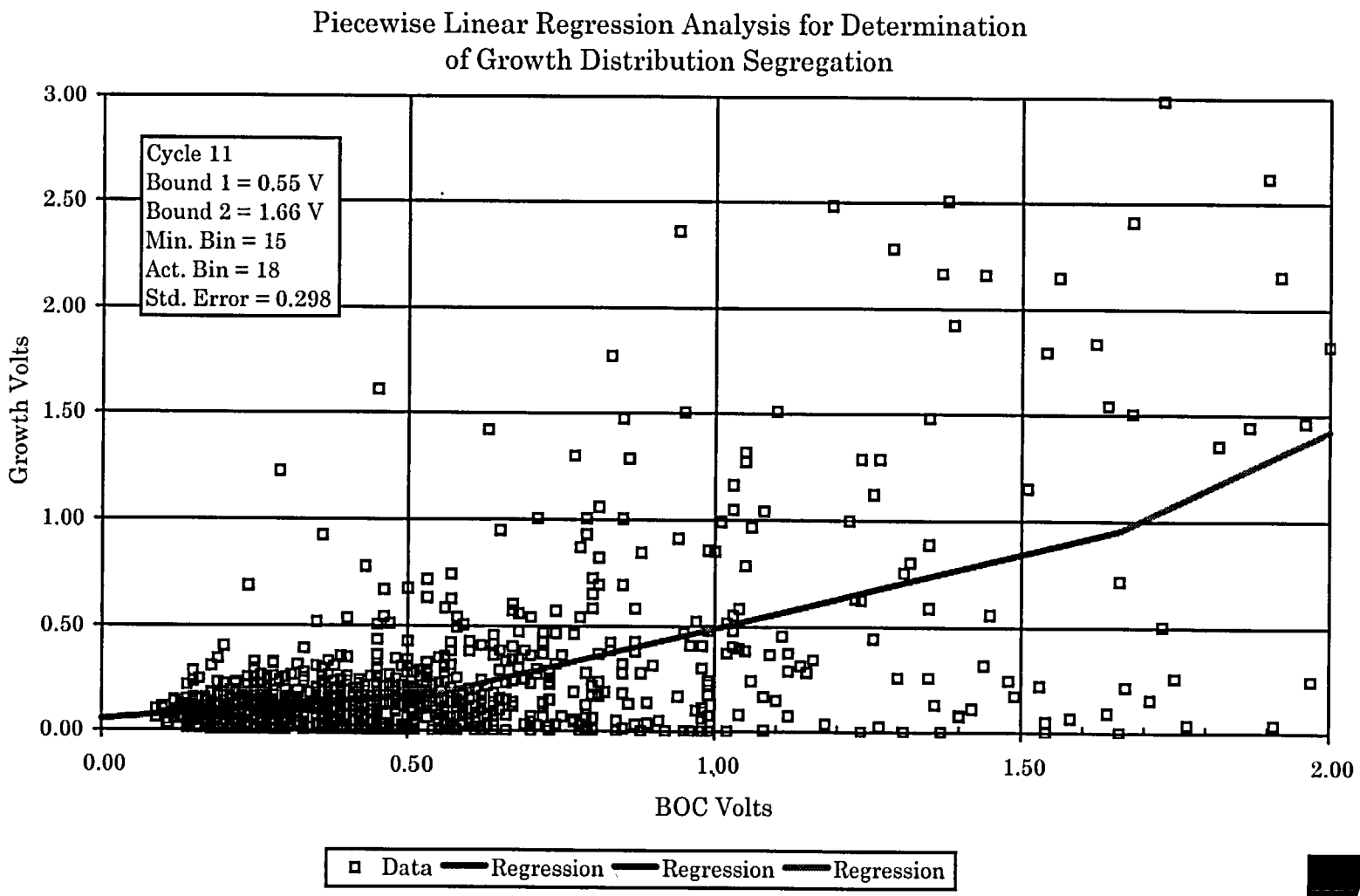
PG&E

Analysis of Cycle 10 & 11 Results

- The Tri-Linear regression is sufficient to identify locations where the data are indicating a different dependent behavior.
- One observation was that very similar results are obtained for different starting values because changes in the standard deviation of the error can be slight.
- **Conclusion** —
  - Bin segregation values of 0.59 and 1.66 Volts are appropriate for the VDG analysis of the ODSCC ARC indications.

PG&E

Cycle 11 Tri-linear Regression



Operational Assessment for 120 Days

- POB and leakage calculations for 120 days
- Margin due to conservative assumptions
  - 21.5 V crack removed from growth
  - Reduced NDE uncertainty for larger voltage flaws (upper bin)
  - Use of Addendum Rev 5 with R44C45 2400 psi burst assumption
  - Calculation for 0.4 EFPY is actually 146 days

PG&E

SG 2-4 POB VDG Calculations w/ 21.5 V

Voltage Breakpoints	Voltage Bin	Comments	POB
0.59V & 1.66V	<=0.59V		4.74E-05
	0 6V - 1 66V	Growth Increased 10%	3 95E-04
	>1.66V (Combined Cycles 10 & 11)	Cycles 10 & 11 Growth	9.89E-03
	Total		**1.03E-02**
NA (Independent Growth)	All	All Indications in Growth	**5.32E-03**

The following inputs were used in the above calculations
1) constant POD of 0.6
2) 0 4 EFPY operating time
3) Plug indications >1.20 volts
4) Addendum 5 correlation plus assumed burst pressure of 2400 psi for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 21 5 v Flaw in Bin 3 Growth File
7) 2 86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws in upper bin

PG&E

SG 2-4 POB VDG Calculations w/o 21.5 V

Voltage Breakpoints	Voltage Bin	Comments	POB
Previous Slide Results			**1.03E-02**
0 59V & 1 66V	<=0.59V		4.74E-05
	0.6V - 1.66V	Growth Increased 10%	3.95E-04
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth w/o 21v	6.89E-03
	Total		**7.33E-03**
0.59V & 1.66V	<=0.59V		4.74E-05
	0 6V - 1 66V	Growth Increased 10%	3.95E-04
	>1 66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth w/o 21v & 5% Uncertainty	6 45E-03
	Total		**6.89E-03**

The following inputs were used in the above calculations:
1) constant POD of 0.6
2) 0 4 EFPY operating time
3) Plug indications >1 20 volts
4) Addendum 5 correlation plus assumed burst pressure of 2400 psi for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 21.5 v Flaw removed from growth distributions
7) 2.86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws in upper bin

PG&E

SG 2-4 Leakage VDG Calculations w/ 21.5 V

Voltage Breakpoints	Voltage Bin	Comments	Leak Rate (gpm)
0.59V & 1.66V	<=0 59V		0.08
	0 6V - 1 66V	Growth Increased 10%	1 30
	>1 66V (Combined Cycles 10 & 11)	Cycles 10 & 11 Growth	6 29
	Total		**8.20**
NA (Independent Growth)	All	All Indications in Growth	**5.59**
0.59V & 1.66V	<=0.59V		0.08
	0 6V - 1.66V	Growth Increased 10%	1 30
	>1.66V (Combined Cycles 10 & 11)	Cycles 10 & 11 Growth with 5% Analyst Uncertainty	5.98
	Total		**7.95**

The following inputs were used in the above calculations:
1) constant POD of 0.6
2) 0.4 EFPY operating time
3) Plug indications >1.20 volts
4) Addendum 5 correlation plus assumed leak rate of 1820 lph for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 21 5 v Flaw in Bin 3 Growth File
7) 2.86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws

PG&E

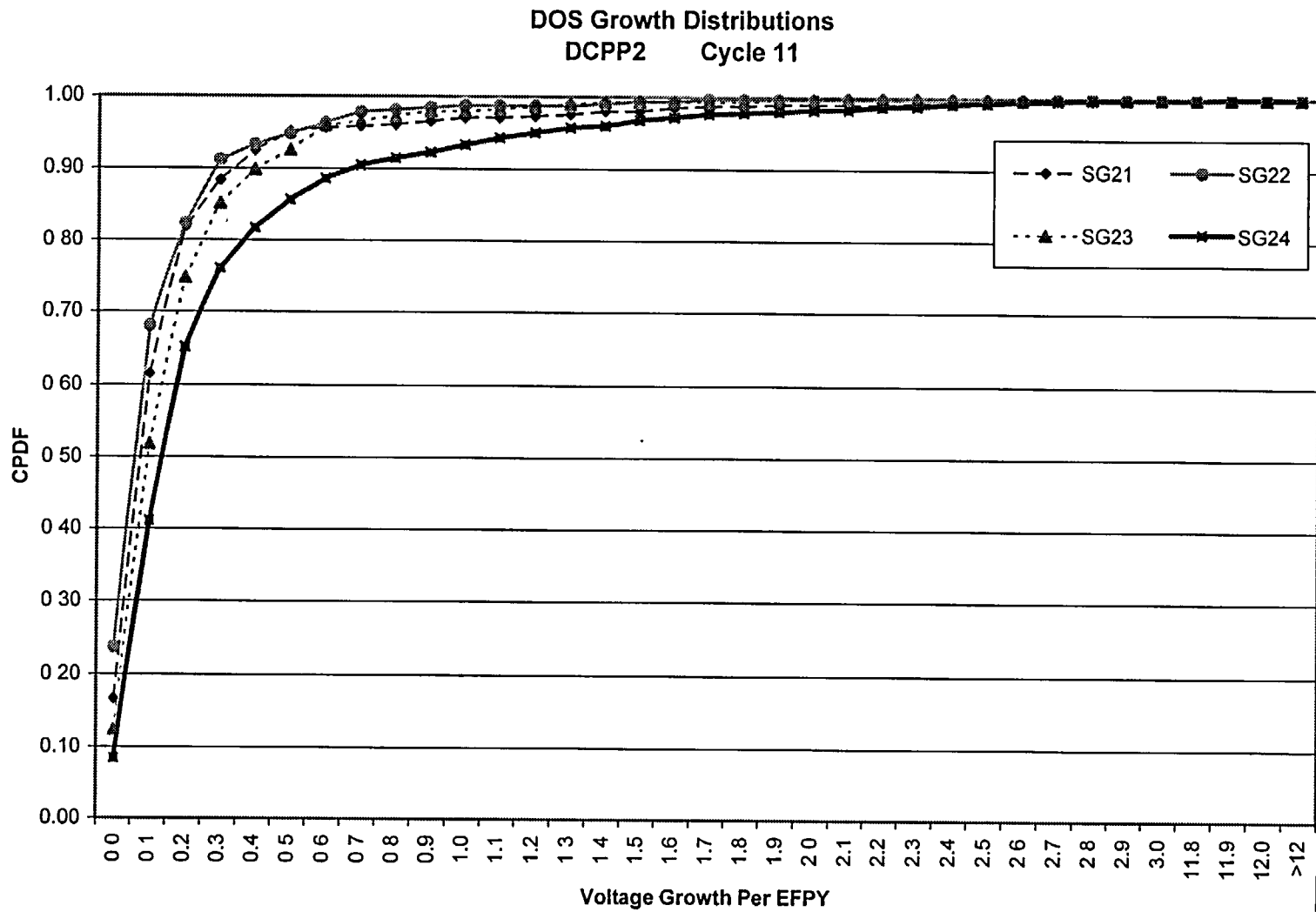
SG 2-4 Leakage VDG Calculations w/o 21.5 V

Voltage Breakpoints	Voltage Bin	Comments	Leak Rate (gpm)
0.59V & 1.66V	<=0.59V		0.08
	0.6V - 1.66V	Growth Increased 10%	1.30
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth w/o 21v	5.19
	Total		**7.11**
0 59V & 1.66V	<=0.59V		0.08
	0.6V - 1 66V	Growth Increased 10%	1 30
	>1 66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth w/o 21v & 5% Uncertainty	5.16
	Total		**7.08**

The following inputs were used in the above calculations:
1) constant POD of 0.6
2) 0.4 EFPY operating time
3) Plug indications >1.20 volts
4) Addendum 5 correlation plus assumed leak rate of 1820 lph for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 21.5 v Flaw in Bin 3 Growth File
7) 2.86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws in

PG&E

Other SG Growth Comparison



Full Cycle 12 – POB Results

Full Cycle Calculations			
0.59V & 1.66V	<=0.59V		2.19E-04
	0 6V - 1 66V	Growth Increased 10%	4.43E-03
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth **w/ 21v**	6 49E-03
	Total		**1.11E-02**
0.59V & 1.66V	<=0.59V		2.19E-04
	0 6V - 1.66V	Growth Increased 10%	4 43E-03
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth **w/o 21v**	1.27E-03
	Total		**5.91E-03**

The following inputs were used in the above calculations
1) DCPP Specific POPCD
2) Full Cycle operating time
3) Plug indications >1.20 volts
4) Addendum 5 correlation plus assumed burst pressure of 2400 psi for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 2.86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws in

PG&E

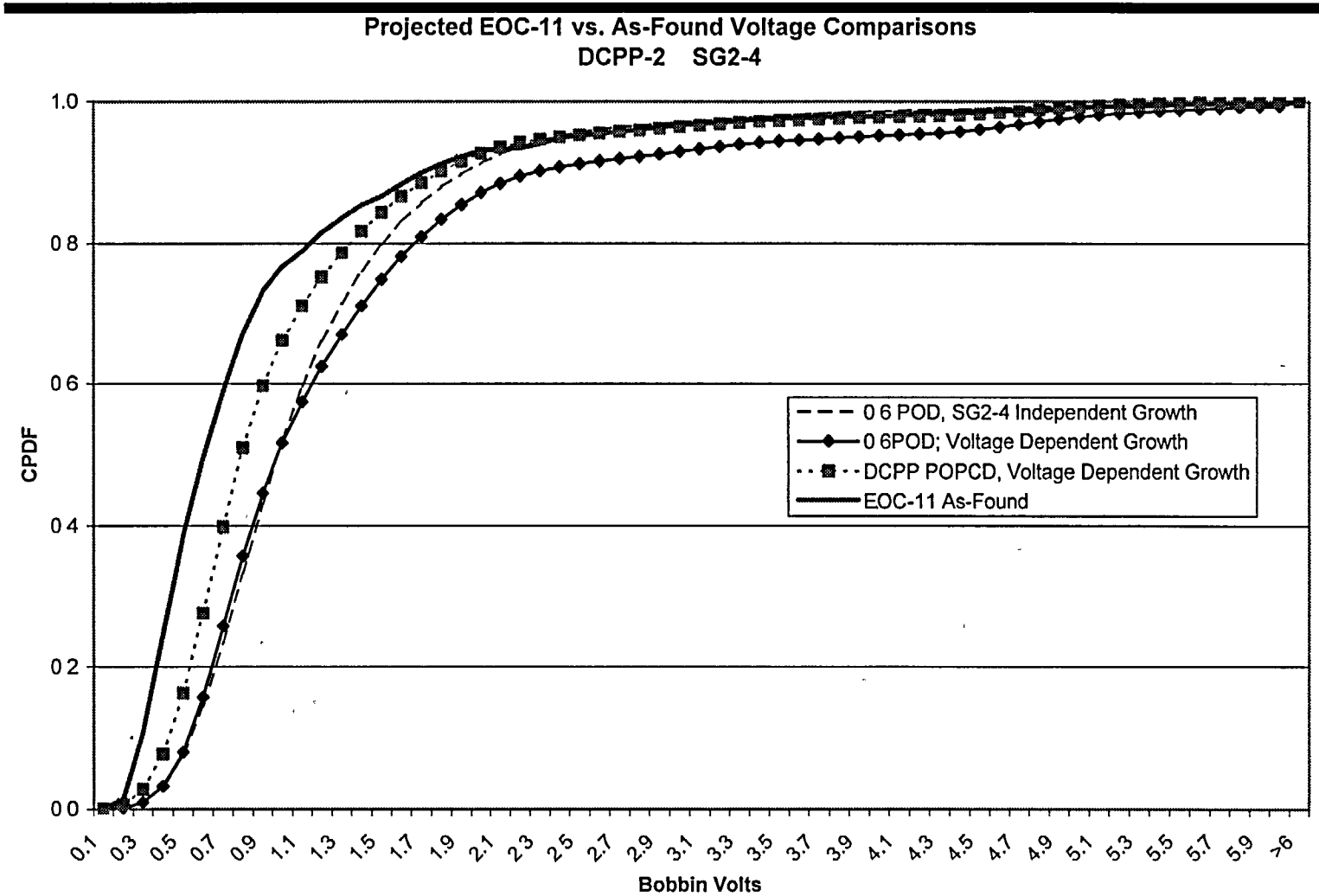
Full Cycle 12 Leak Rate Results - GPM

Full Cycle Calculations			
0 59V & 1.66V	<=0.59V		0.63
	0 6V - 1.66V	Growth Increased 10%	5.99
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth **w/ 21v**	0 86
	Total		**7.90**
0.59V & 1.66V	<=0.59V		0 63
	0 6V - 1.66V	Growth Increased 10%	5 99
	>1.66V (Combined Cycles 10 & 11)	Cycles 10&11 Growth **w/o 21v**	0.61
	Total		**7.64**

The following inputs were used in the above calculations:
1) DCPP Specific POPCD
2) Full Cycle operating time
3) Plug indications >1.20 volts
4) Addendum 5 correlation plus assumed burst pressure of 2400 psi for SG24 44-45
5) No 21 Volt Flaw in BOC
6) 2.86v/EFPY growth from SG21 added to SG24 upper growth distribution to obtain 3 largest flaws in

PG&E

Benchmarking



Initial Root Cause Evaluation

- Assessment of VDG behavior in cycle 10 per EPRI Addendum 5 methods did not conservatively predict EOC conditions
  - Industry guidance for VDG needs enhancement for this situation – our statistically based binning is a first step
- Assumptions for R44C45-2H flaw growth (left in service at ARC limit) did not predict the exponential voltage increase actually observed
  - Industry guidance for use of additional RPC screening of ARC flaws near 2 bobbin volt limit needs improvement – our 1.2 volt plugging limit has eliminated this issue for cycle 12

PG&E

Locked TSP Update

- Background
  - WCAP-14707 provides technical bases for limited TSP displacement for dented or packed TSP crevices (2/23/98 NRC submittal)
  - NRC staff review (received 1/18/2000)
    - Review of hydraulic analyses not complete
  - ANL Sensitivity Studies of Failure of Steam Generator Tubes during Main SLB and Other Secondary Side Depressurization Events (NUREG/CR-xxxx) (Manuscript completed 12/02)
    - Includes review of WCAP-14707 results

PG&E

Issues from NRC Staff Review

- Small database for tube to TSP displacement locking forces and leak rates under accident conditions
  - Can be overcome with additional plant specific tube pulls and laboratory leak rate testing as well as through the application of conservative margins
- Policy related issue – Whether it is appropriate to rely on corrosion products (a non-Code material) to ensure reactor coolant pressure boundary integrity

PG&E

SLB Hydraulic Loads on TSPs

- WCAP-14707
  - TSP pressure drops calculated by RELAP5 and TRANFLO
    - RELAP5 loads increased by factor of 1.5 for uncertainties based on sensitivity studies
- ANL NUREG
  - Pressure drops calculated by NRC staff member using TRAC-M

PG&E

Conclusions on SLB Loads on TSPs

- TRAC-M analyses
  - Peak loads lower by 10% at top TSP and by more than a factor of 3 at lower TSPs
  - TRAC-M loads show time shift from plate to plate while RELAP5 loads occur at approximately the same transient time (more conservative for displacement times)
  - TRAC-M pressure load duration slightly broader than RELAP5 (slightly non-conservative)
  - Both industry and staff results show bounding pressure drops about factor of 2 higher than codes
- ANL conclusion: Little need for additional T&H analyses for SLB transients
- Overall conclusion: RELAP5 loads increased by 1.5 factor provide bounding loads for TSP displacement analyses

PG&E

Comparison of RELAP5 to TRAC-M

TSP Peak Differential Pressures (psi) from RELAP5 (WCAP) and TRAC-M for Large Break SLB at Hot Standby Conditions (Limiting Event Bounding Loads)

TSP	RELAP5	TRAC-M	Ratio
7 (top)	9.6	8.57	1.12
6	8.1	5.06	1.60
5	6.1	3.84	1.59
4	4.5	2.63	1.7
3	3.2	1.16	3.2
2	2.0	0.15	13
1	1.9	-0.33	-5.8(1)
Note 1: Upward loads in RELAP, Down in TRAC-M			

PG&E

Axial Pull Force Tests for Tube to TSP Displacement

- Breakaway force database (WCAP and RAI responses)
  - Lab RT (4 tests): 320 to 3000 lbs
  - Lab Hot (4 tests): 2184 to 4790 lbs
  - Foreign pulled tubes (reduced by about 50% by chemical cleaning
    - RT (10 tests): 1313 to 4496 lbs
    - Hot (4 tests): 1798 to 3664 lbs
  - Domestic pulled tubes – see table (adds 1 new DCPP value)
- Conclusion
  - Maximum SLB load of 60 lbs/intersection is much lower than required forces to initiate tube to TSP displacement for packed tube to TSP crevices

PG&E

Domestic Pulled Tube Breakaway Forces for Non-dented Intersections

Plant	Tube	TSPs Included	Total Breakaway Force (lbs)	Average RT Breakaway Force (lbs)
DCPP-2	R2C66	1-2	1000	500
	R44C45	1-2	1000-1500	500-750
	R35C57	1-2		
L	R29C70	1-3	7955	2652
	R30C64	1-3	2775	925
	R18C70	1-3	4955	1652
Z-2	R11C27	1-2	4600	2300
	R21C71	1-5	9000	1800
Average				
Standard Dev.				

PG&E

WCAP-14707 Leak Test Data

- Lab specimens (non-prototypic denting)
  - Supports trend to zero leakage with denting
- Non-dented pulled tubes from Dampierre-1
  - Average leak rate for 7 tests at 1450 psid - <3E-04 gpm
  - Average leak rate for 5 tests at 2495 psid - <1.5E-04 gpm
  - Negligible increase in leak rates with TSP displacements up to 0.16"
  - Negligible effect of chemical cleaning up to about 0.16" TSP displacements
    - Chemical cleaning removed deposits from crevice for about 0.08" from TSP edges

PG&E

DCPP-2 In-Situ Test Results

- Room temperature leak test results
  - 13 tests performed
  - 8 did not leak at NOP conditions
    - Largest leak = 0.004 gpm (R44C45, no SLB test)
  - All leaked at SLB conditions
    - Largest leak = 0.0232 gpm (SG 2-1, R30C41)
- Crevice gap closure due to ΔP and temperature
  - ΔP: NOP = 0.00028, SLB = 0.00051
  - Temperature (600°F) = 0.0034 (not included in tests)
- Conclusions
  - Very likely no leakage at operating temperatures
  - Cycle 11 operating leakage likely due to U bend indications

PG&E

Structural TSP Displacement Analyses

- ANL sensitivity analyses
  - Model a SG quadrant
    - WCAP modeled two quadrants with two models to assess all tube locations
  - Static-elastic calculations expected to yield conservative TSP displacements
    - WCAP is a dynamic time history analysis
  - Looked at effect of a limited number (≤10) locked tubes per TSP quarter
    - WCAP assumes all TSPs have packed crevices

PG&E

Conclusions from ANL Analyses

- ANL Sensitivity Analysis Results
  - Tube bending stresses resulting from the MSLB are negligible
  - Tube axial stiffness concluded to be several orders of magnitude higher than out-of-plane support plate stiffness
  - Plate displacements are shown to be dramatically reduced if only a single tube (per plate quarter) is considered to be locked, 0.44 inch to 0.054 inch. The displacement at the tube/TSP interface is reduced to 0.013 inch.
  - With as few as four locked tubes per plate quarter, the axial load in the tubes are less than yield (5 kips)
  - Axial loads up to 5000 pounds (tube yield) do not have a significant effect on burst pressure or crack opening characteristics for axial cracks of 0.5 inch in length or less
- Conclusion: The results of the sensitivity study are supportive of the analysis results in WCAP-14707

PG&E

Overall Locked TSP Conclusions

- All new information supports WCAP-14707 evaluations
  - Staff TRAC-M hydraulic loads less than WCAP
  - ANL structural sensitivity studies support WCAP results
  - New DCPP-2 pulled tube breakaway forces adequate to support locked TSP analyses
  - New DCPP-2 in-situ test results support little or no leakage from indications at TSP intersections

PG&E

Risk Assessment

- Objective
  - Assessment of risk significance for operating a full cycle following 2R11, leaving in service SG tubes with small ODSCC indications
  - The Risk Assessment (RA) is consistent with TS and GL 95-05, Section 6.a.3 requirement
    - If the calculated conditional POB under postulated MSLB condition exceeds 1.0E-02, licensees should provide an assessment of safety significance of the calculated POB prior to returning to service.
- Risk Significance Criteria
  - Large Early Release Frequency (LERF) figure of merit and NUREG 1.174 LERF criteria are used to determine risk significance

PG&E

Risk Assessment

- Major Assumptions and Assertions
  - ODSCC indications are covered by the TSPs, do not directly communicate with the SGs, and their leakage to the SGs under normal and most accident conditions is restricted by the TSPs' packed crevices, if TSPs remain in place.
  - The DCPP TSPs are locked in position and will not be vertically displaced under normal and most accident conditions.
  - The worst case end of cycle freespan calculated conditional POB (i.e., 0.06) is used for this risk assessment.
    - POD of 0.6, 21.5 V indication included, 1.2 V plugging
  - All containment bypass sequences are conservatively assumed to contribute to the LERF figure of merit.

PG&E

Risk Assessment

- Possible Impacts
  - Impact on Spontaneous Tube Rupture Frequency. No credible impact due to
    - Large leaks during normal operation not possible due to tight gap between TSPs and tubes.
    - Axial ODSCC indications will not propagate outside of the TSP area.
    - In-situ test of the largest degraded tube supports this judgment.
  - Impact on Accident Mitigation Capability.
    - Four Accident classes were evaluated and one class was quantified.

PG&E

Risk Assessment

- Possible Impacts on Accident Mitigation Capability (Cont.)
  - Class 1- Events with potential to vertically displace TSP but no additional ΔP across tubes. Seismic events are potential contributors but are not credible because
    - seismic-induced load on the TSP is negligible
  - Class 2- Secondary side depressurization sequences that could potentially vertically displace TSP and significantly increase ΔP across tubes.
    - Major SLB and MFW breaks
    - This Class is possible contributor. Contribution is quantified.

PG&E

Risk Assessment

- Possible Impacts on Accident Mitigation (Cont.)
  - Class 3- Severe accident thermal challenge-induced tube rupture events.
    - High and Dry core damage sequences causing failure of flawed tube prior to failure of other RCS components
    - Not credible because TSPs will remain in place
      - They are not directly exposed to the high temperatures condition.
      - Comparatively, TSPs are very thick in the radial direction.
  - Class 4- Anticipated Transient Without Scram (ATWS) sequences (High Pressure).
    - Not credible since no potential to vertically displace TSPs

PG&E

Risk Assessment

Sensitivity Cases	LERF
Base Case	**1.80E-09**
Use POPCD POB Results	3.55E-10
NUREG 0844 Results	5.25E-10
NUREG 0844 Results & POPCD POB Results	2.50E-10
Increase POB from 0.06 to 1.0	2.99E-08
Increase Prob. TSP to 0.05	1.00E-07
Use POPCD POB Results &TSP 0.3	1.00E-07
NUREG 0844 Results & TSP 0.2 (Limit)	1.00E-07

PG&E

Risk Assessment

- Conclusion:
  - The safety significance, as measured by the change in the LERF figure of merit, associated with leaving tubes with ODSCC flaws in service for full cycle 12 is low.

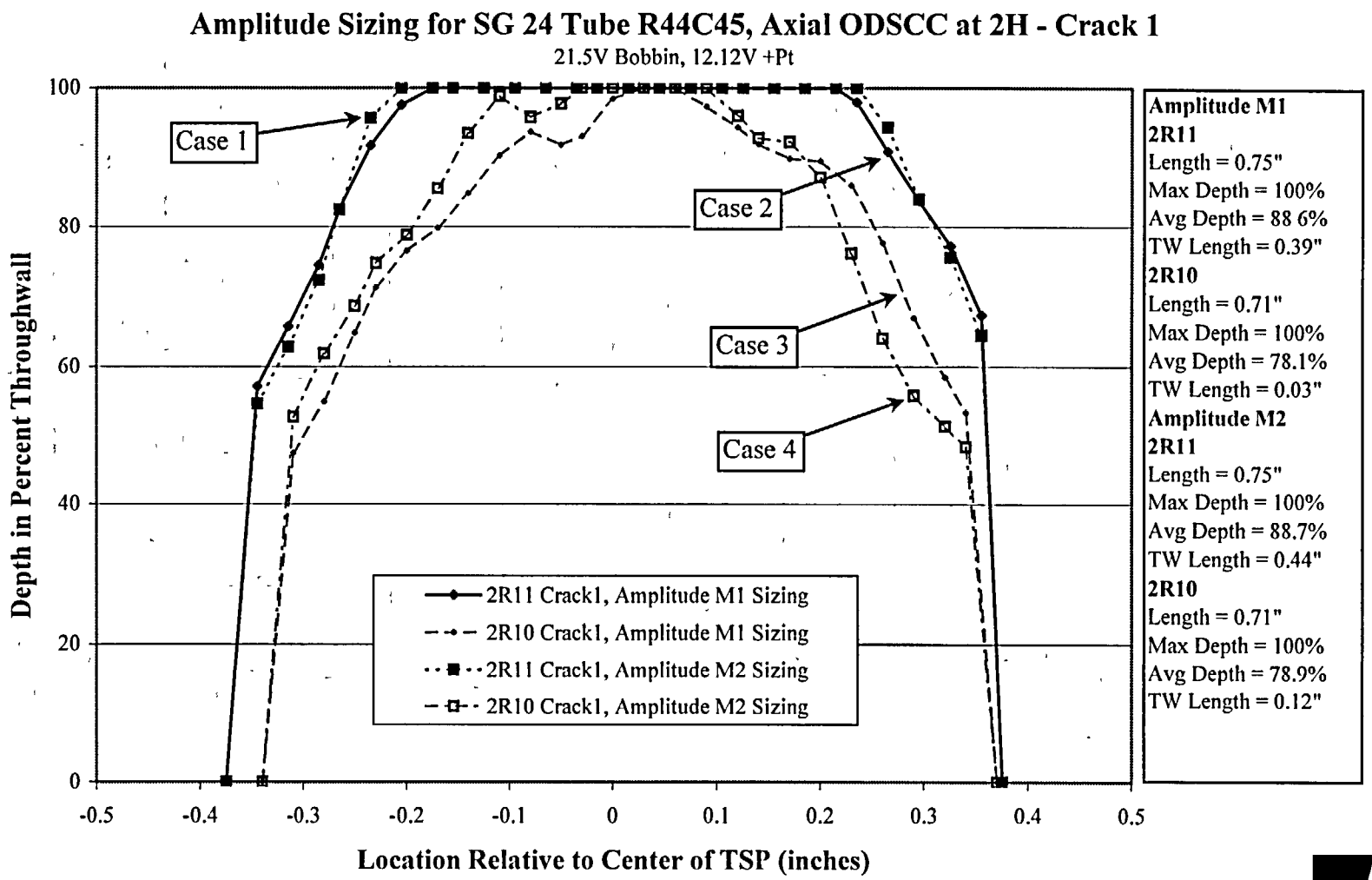
PG&E

Plans for Cycle Beyond 120 Days

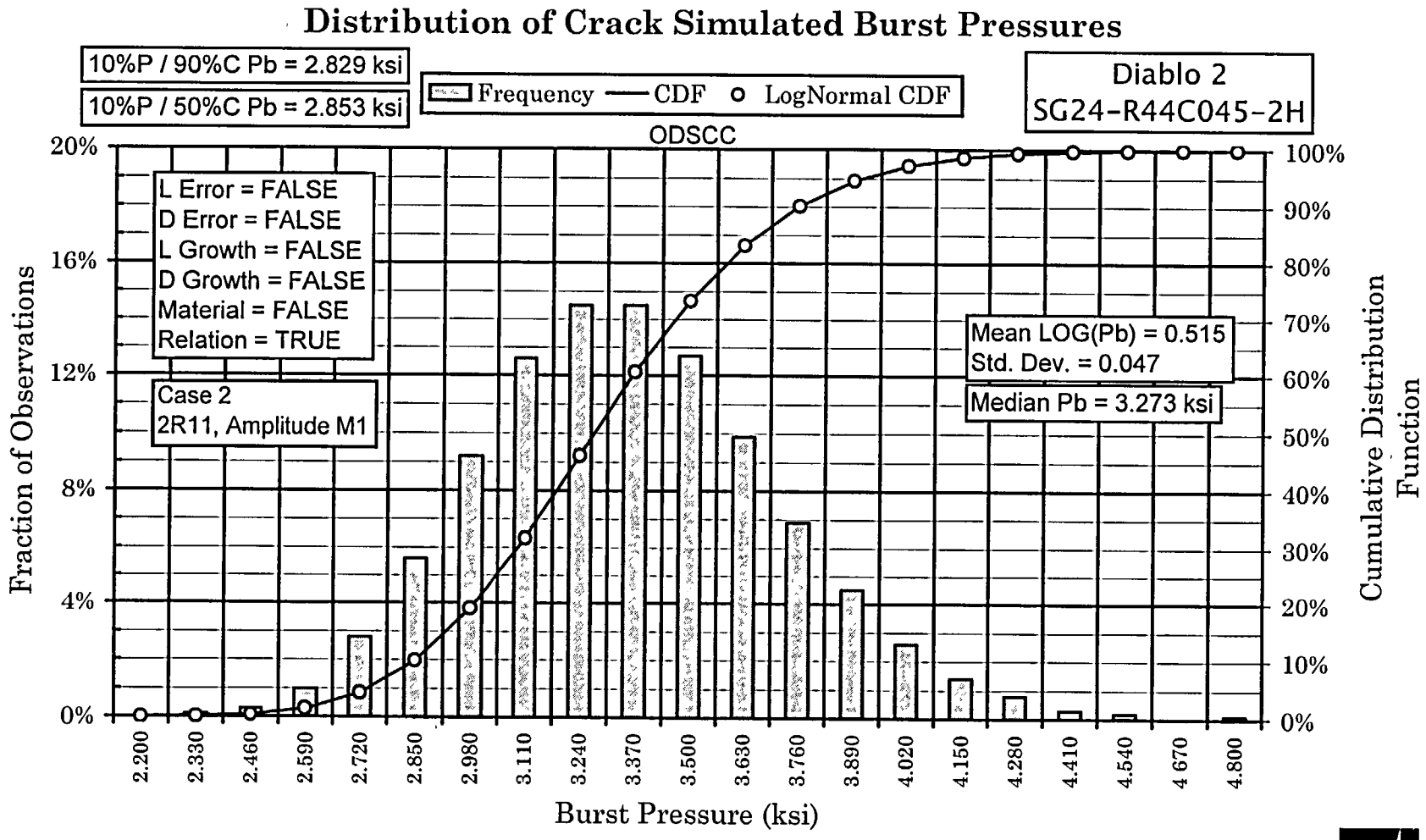
- Complete laboratory tests and examinations on pulled tubes
- Support DCPP POPCD approval
- Recalculate OA for full cycle with pulled tube results
  - Predicted Full Cycle (POPCD) Results:
    - POB 5.9E-03 (w/o 21.5 V flaw)
    - Leakage 7.08 gpm

PG&E

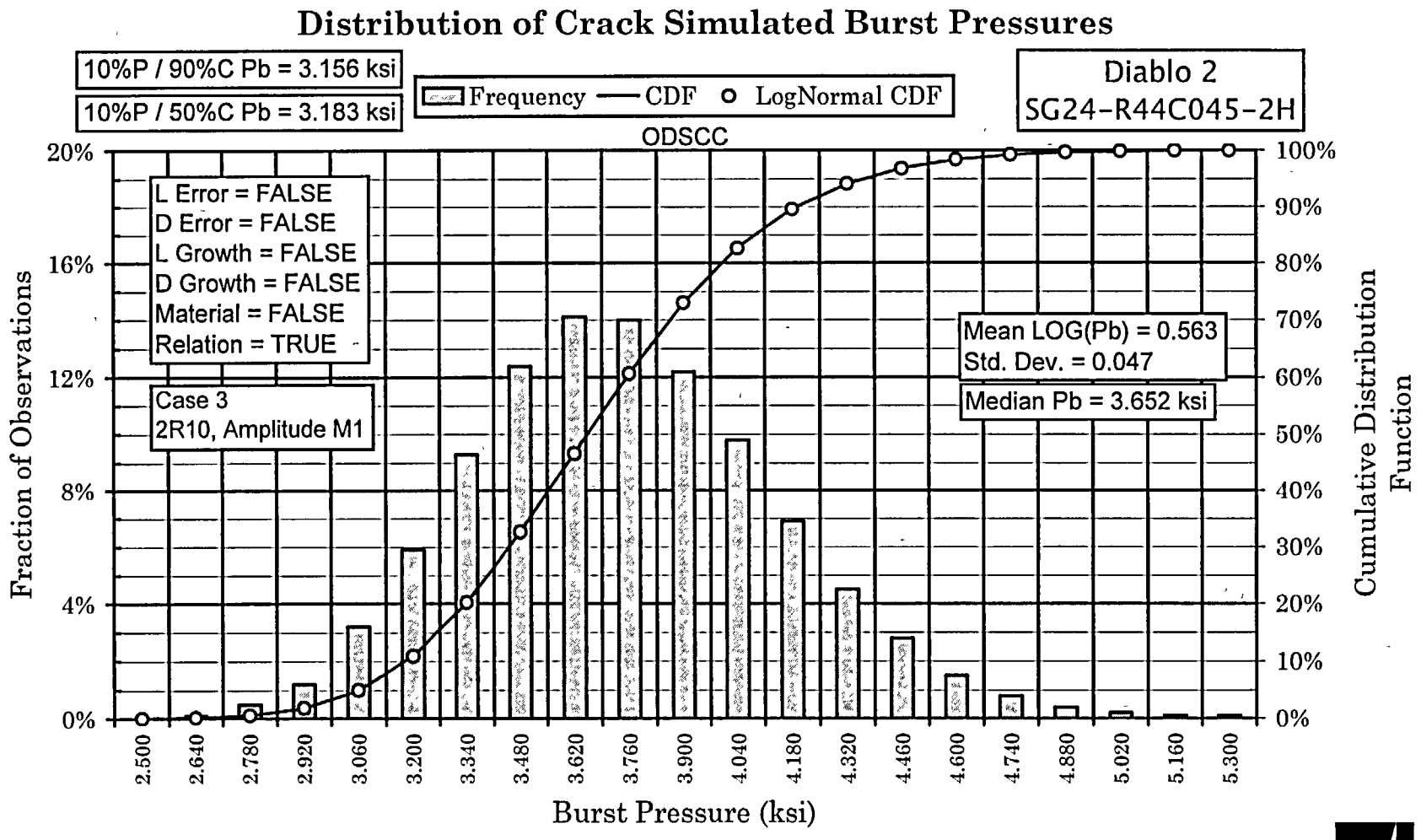
R44C45 – 2H Structural Evaluation



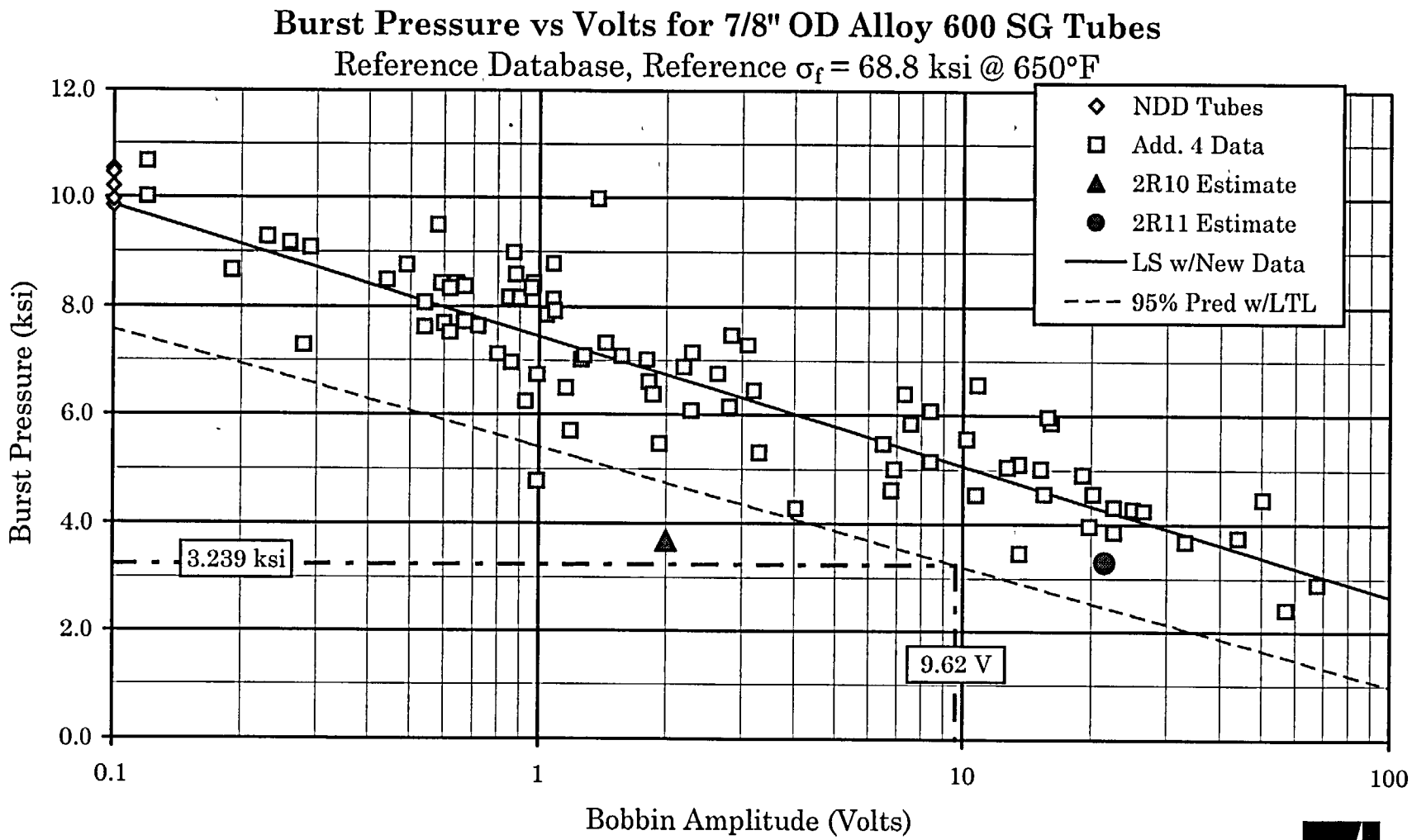
Case 2, 2R11 Nominal, M1



Case 3, 2R10 Nominal, M1



Addendum 5 ARC Database



Other PG&E Actions

- More aggressive condenser sea water leakage performance objectives
- Chemical cleaning will occur in R12 outages
- Mechanical locking TSPs is being considered for 2R12
- SG replacement is currently scheduled for R15s
  - Will evaluate acceleration to R14s

PG&E

U Bend Inspection Scope and Results

- Background
- Description of findings and morphology
- Historical review
- Visual examinations
- Manufacturing
- Root cause
- Future plans

PG&E

Background

- Prior U bend RPC inspections
  - 100% of Rows 1 and 2 each outage (+Point in 2R7+)
  - 20% Row 3 in SG 2-3 in 2R8 and 2R9 (expansions)
- 2R11 U bend planned +Point inspections
  - 100% of rows 1 and 2
  - 100% row 3 in SG 2-4, 20% row 3 in SG 2-1, 2-2, 2-3
- In response to Comanche Peak high row U bend indication (axial ODSCC) additional +Point:
  - 100% of >5 volt dings in U bends
  - 100% of free span indications not traceable to baseline
- Secondary side pressure test conducted in SG 2-4 to locate primary to secondary leak rate from last several cycles
  - SG 2-4 R5C62 U bend leaking

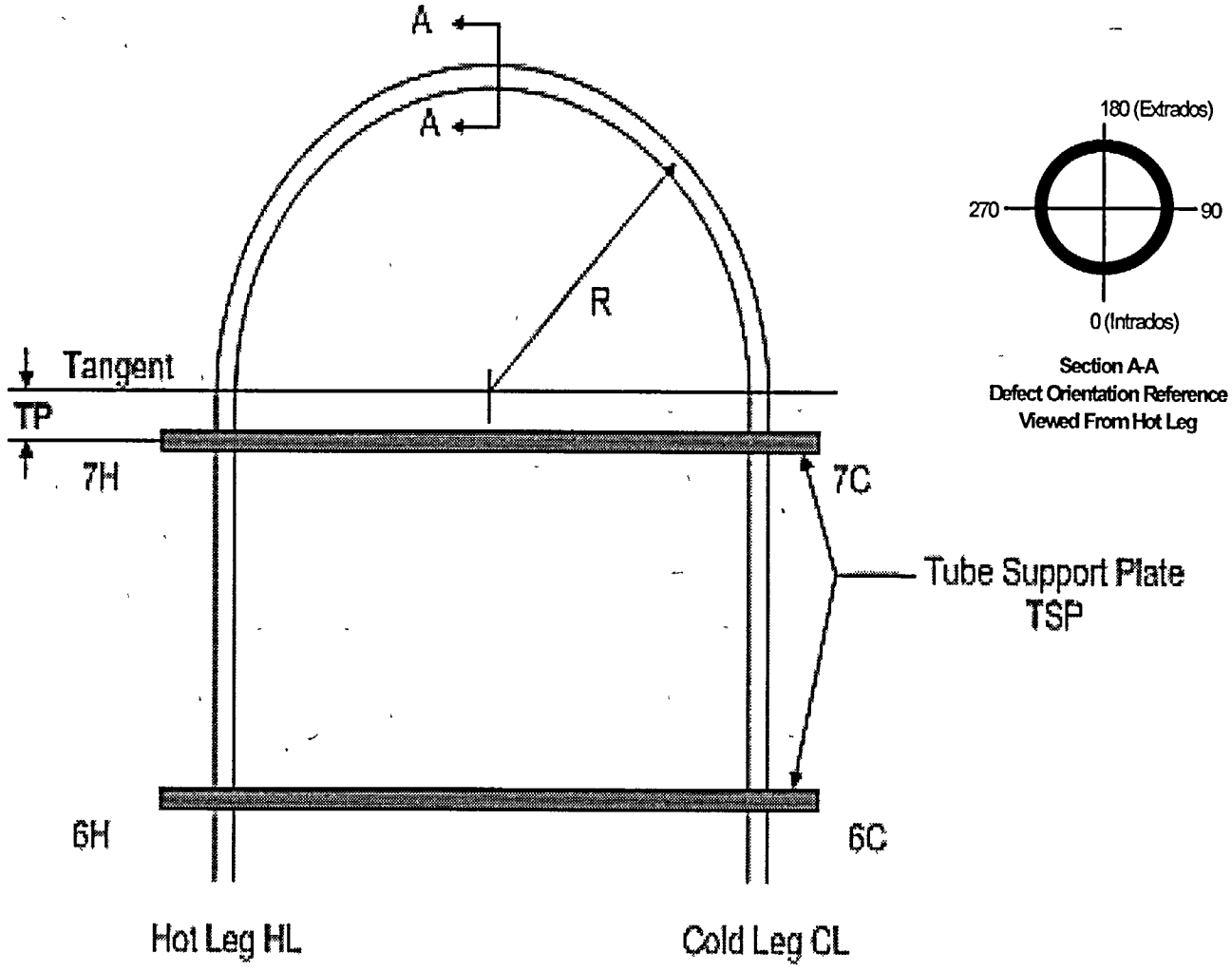
PG&E

2R11 Actual U bend Inspection Scope

- +Point probe examination of the complete U bend region of all in-service tubes in all four steam generators
- Additional inspections with the X-Probe
- Additional inspections with the rotating pancake probe
- Some inspections with the high frequency +Point probe

PG&E

U bend Diagram

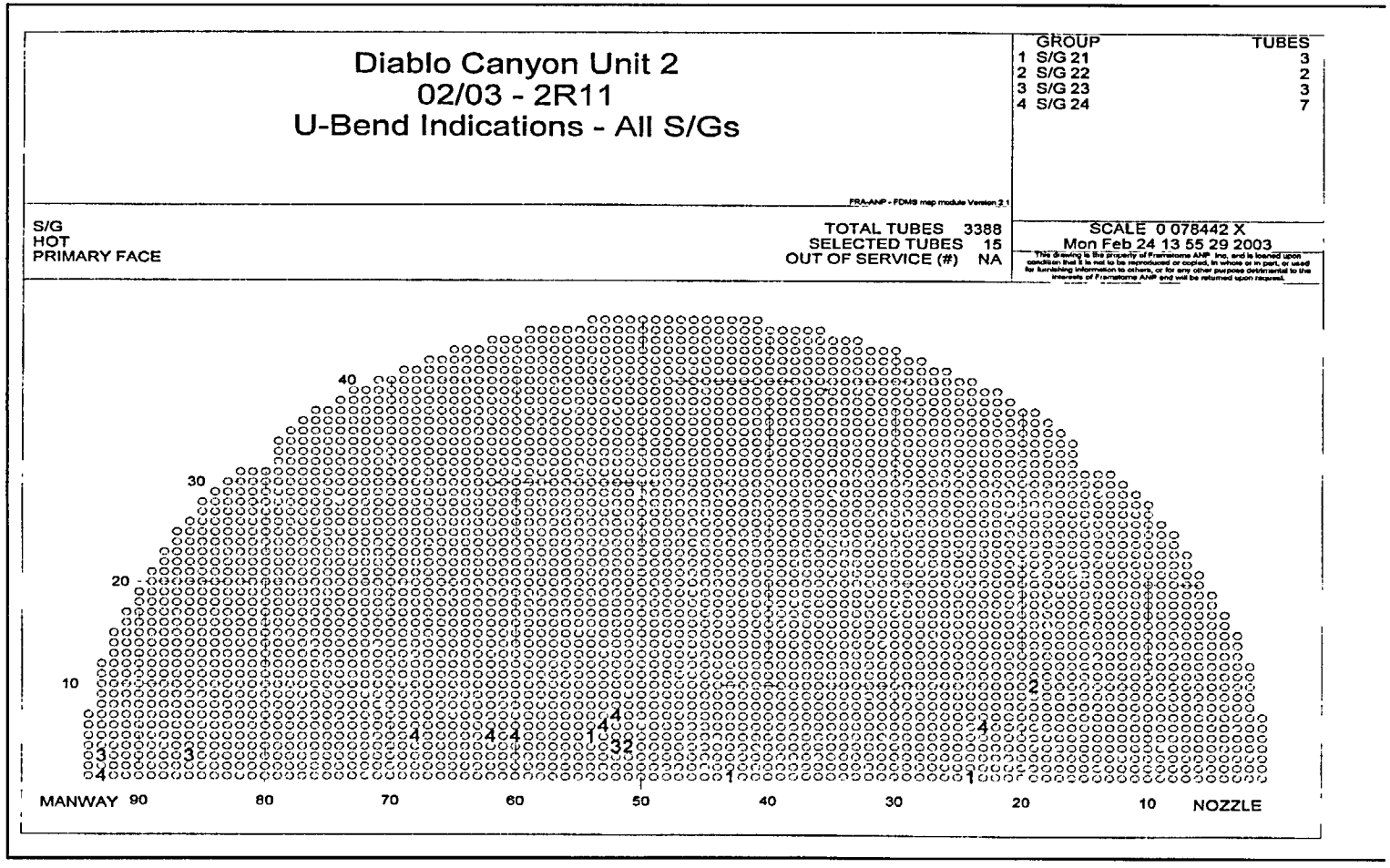


Summary of U Bend Indications

SG	Row	Col	Orientation	Axial Position	Number of +Point Indications
21	1	24	axial	HL tangent	1
21	1	43	circ	HL tangent	1
21	5	54	circ	throughout bend	7
22	4	51	circ	throughout bend	21
22	10	19	circ	throughout bend	2
23	3	86	circ	CL tangent	2
23	3	93	circ	CL tangent	1
23	4	52	circ	CL tangent	1
24	1	93	axial	HL tangent	1
24	5	60	circ	throughout bend	3
24	5	62	circ	throughout bend	35
24	5	68	circ	throughout bend	5
24	6	23	circ	throughout bend	5
24	6	53	circ	CL tangent	1
24	7	52	circ	throughout bend	9

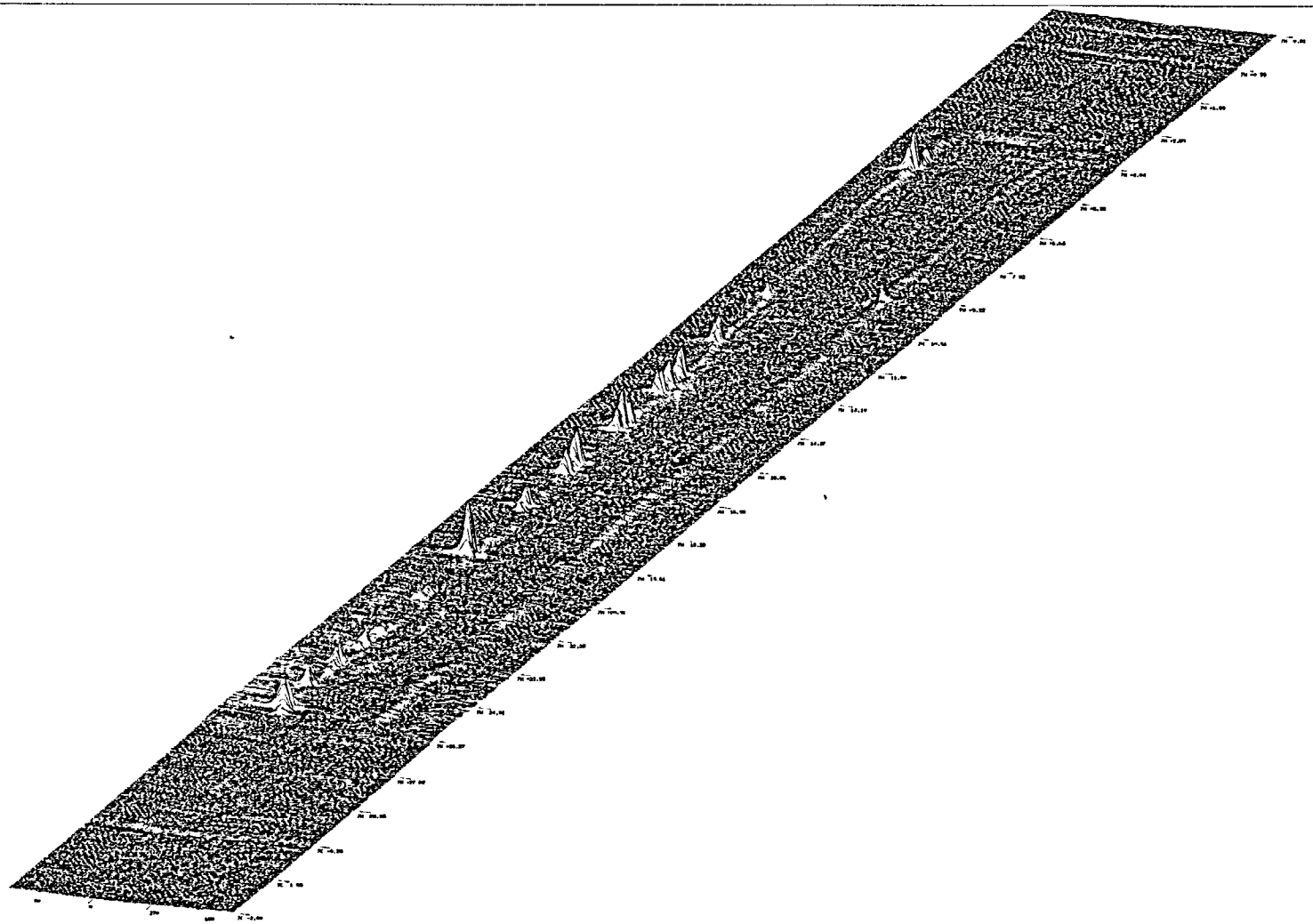
PG&E

Distribution Of Indications



The majority of the indications, for all steam generators, are concentrated in a few basic areas of the tube bundle

SG 2-4 R5C62 +Point Terrain Plot



Morphology

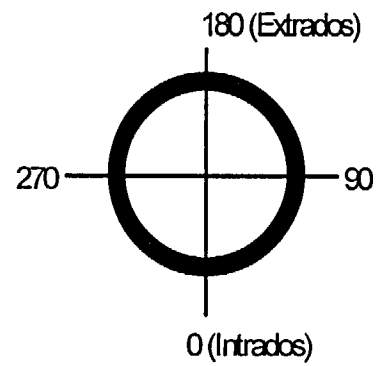
- The indications originate from the inside surface of the tube and are circumferential but slightly off-axis
- The indications are aligned within a "ridge" signal, except for one indication
- Most tubes have indications along only one "ridge" and only 3 of the tubes have indications on two sides of the tube
- The "ridges" were determined to be caused by tube ovalization and are common to all plants reviewed including new replacement SG tubing
- The flaw lengths are short and, for the most part, contained within the "ridge" signal
- Tubes with a single indication have it at the CL tangent, except for one
- A number of the indications in SG 2-4 R5C62 have considerably higher +Point voltages than the other 11 tubes

PG&E

Angular Position

TABLE 3 – ANGULAR POSITION OF THE INDICATIONS BASED ON THE DOWN LOCATOR

SG	ROW	COL	POSITION (degree)	POSITION (For Indication on Opposite Side)
21	5	54	277°	-
22	4	51	272°	89°
22	10	19	272°	-
23	3	86	300°	105°
23	3	93	302°	-
23	4	52	302°	-
24	5	60	287°	-
24	5	62	278°	88°
24	5	68	299°	-
24	6	23	294°	-
24	6	53	-	86°
24	7	52	273°	-



Section A-A
Defect Orientation Reference
Viewed From Hot Leg

The angular position of the indications in 11 tubes is the same, meaning the indications are on the same side of the tube in these cases

Historical Data Review

- Detected indications in tube R5C62 as far back as 1996, slow growth based on bobbin voltage and increasing number of indications over time
  - Bobbin indications only found after flaws located with +Point
- Could not detect indications in any of the other tubes because of their small amplitude, orientation and difficult location
- There were no indicators in the bobbin or +Point data that could be used to identify susceptible tubes

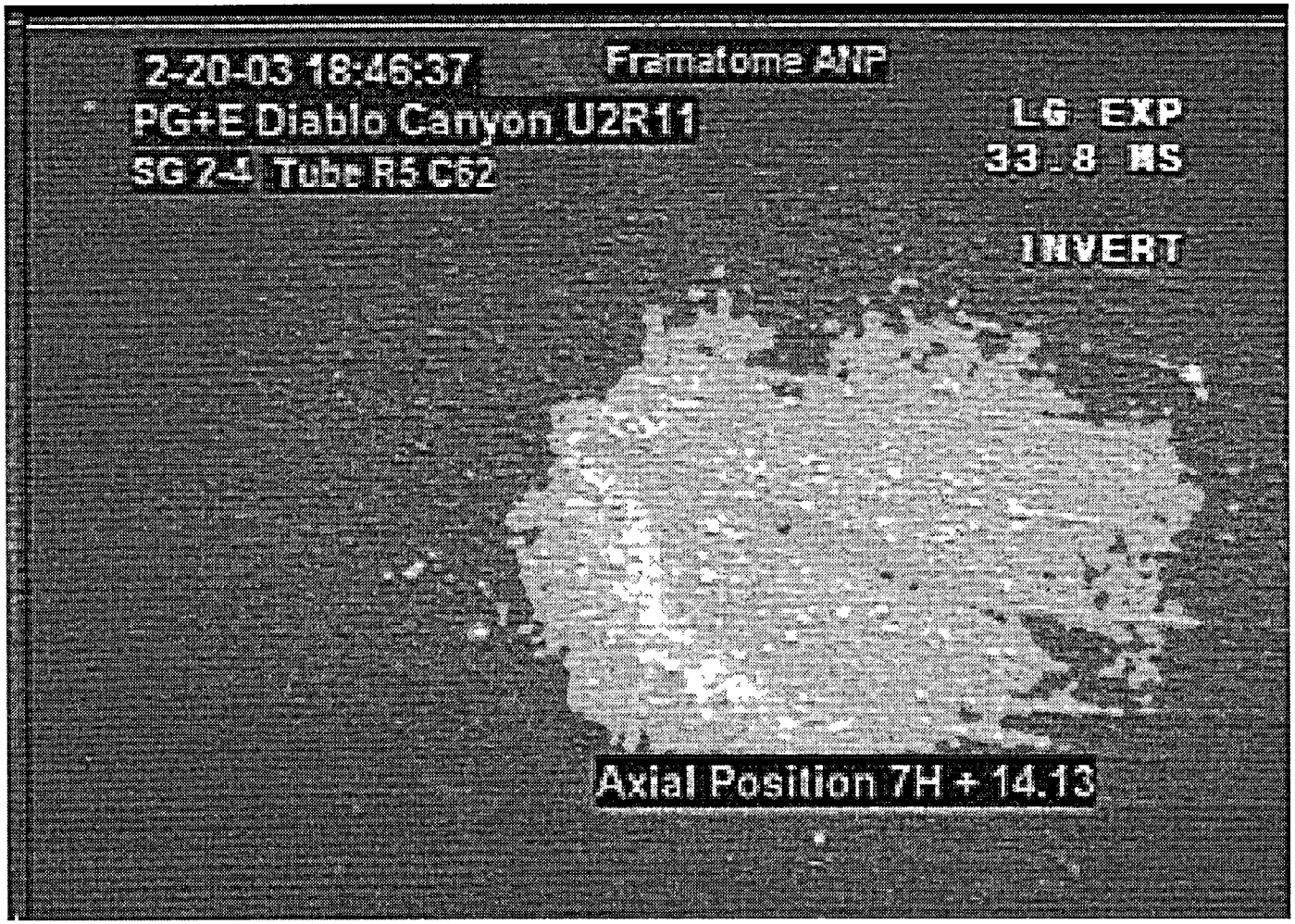
PG&E

Tube ID Visual Inspection Summary Scope

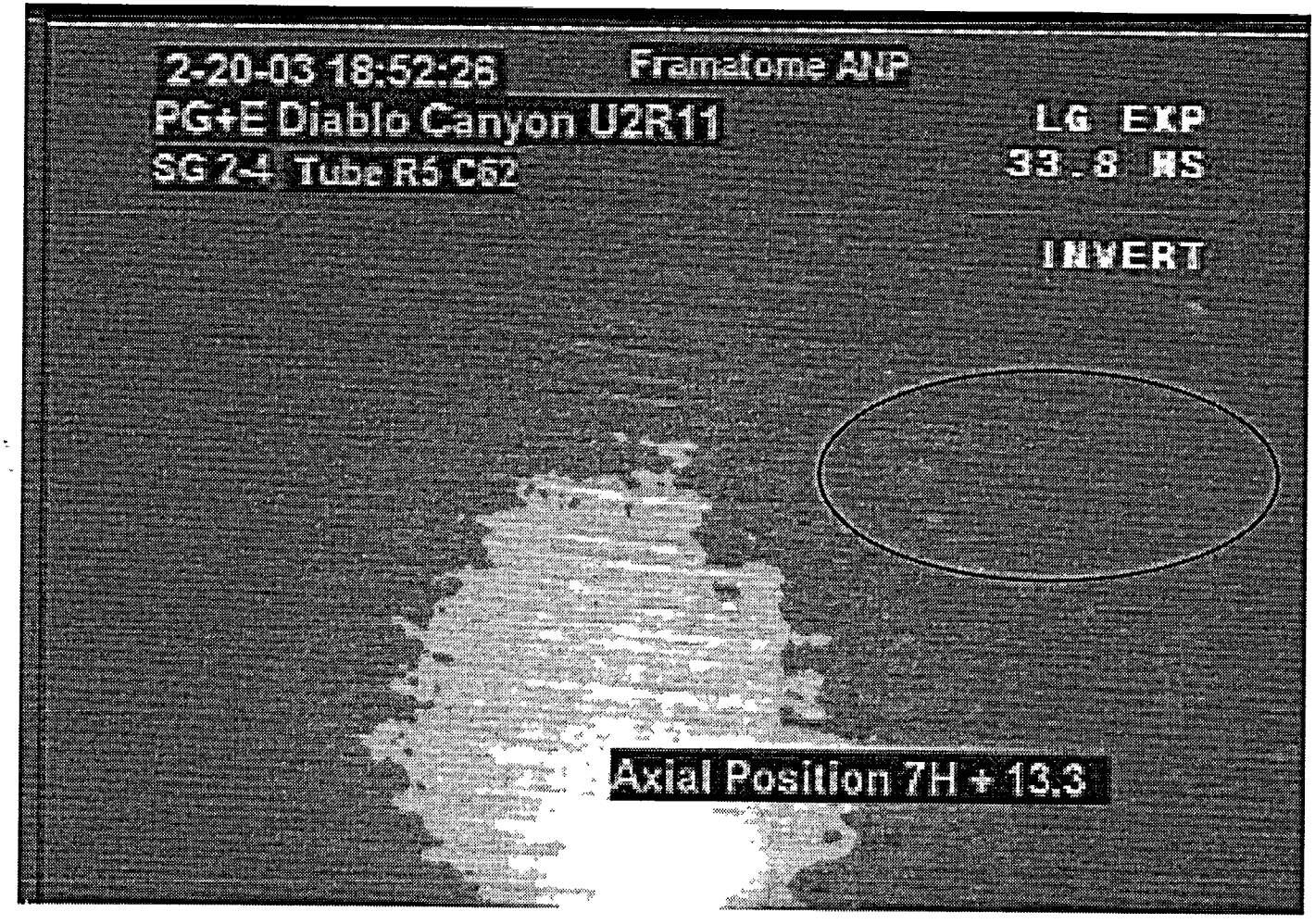
- Performed visual inspections in the 15 tubes with indications:
  - 3 Row 1 U bends
  - 12 Row 3 to 10 U bends
- U bend visual inspection results were generally consistent with ECT data with respect to flaw location, orientation and magnitude

PG&E

PWSCC in R5C62 Flank



PWSCC in R5C62 Flank



In Situ Test Results

Insitu Results for Tubes with U-Bend Indications								
SG	Row	Column	Why Test?	NOP (gpm)	SLB (gpm)	3dP (gpm)	Result	Notes
21	1	24	ID SAI U-Bend	0.0000	0.0000	0.0000	Passed	
21	1	43	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	(1)
21	5	54	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
22	4	51	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
22	10	19	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
23	3	86	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
23	3	93	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
23	4	52	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	(2)
24	1	93	ID SAI U-Bend	0.0000	0.0000	0.0000	Passed	(3)
24	5	60	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
24	5	62	ID Circ U-Bend	(4)	0.0040	0.0456	Passed	
24	5	68	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
24	6	23	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
24	6	53	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	
24	7	52	ID Circ U-Bend	0.0000	0.0000	0.0000	Passed	

Notes:
(1) Transient flow with pressure increase to 4750 psi
(2) Transient flow with pressure increase to 5000 psi
(3) Transient flow with pressure increase to 4750 psi and 5000 psi
(4) No leak data was noted at NOP

PG&E

Tube Manufacturing and Bending

- SG 2-1, 2-2, 2-3, 2-4, 1-1, and 1-2 tubing was made and bent at Blairsville.
- SG 1-3 and 1-4 tubing was made and bent at Huntington Alloy.
- The tubes were inspected by eddy current, UT (for wall thickness), and visual. The tubing was boxed and shipped to Tampa where the SGs were assembled.
- All tubes bent with a concave form. Blairsville used a stationary form, Huntington used a rotating form.
- Rows 1 through 10 used a concave pressure die. Rows 11 and higher used a flat pressure die.
- Rows 1 and 2 used a ball mandrel.

PG&E

Root Cause

- Based on the investigation and analysis performed to date, PWSCC is the cause for the indications found in the U bend
- All of the factors required for the onset of PWSCC in the U bend region are present, specifically:
  - critical service environment: RCS inventory at normal operating temperature and within specified chemistry
  - time at temperature: 8 to 14 EFPY to incipient cracking
  - susceptible material: Mill annealed Alloy 600
  - significant tensile stress (residual plus operating) that are a significant fraction of the yield strength
  - residual stresses are an inherent result of the bending process

PG&E

Future Plans

- Document all of the information that was used as the basis for the cause analysis
- Review Framatome report and Westinghouse report (reports will be made available to NRC)
- Issue cause analysis report by March 20, 2003 (40 days from initiation of Non Conformance Report)
- Determine critical area for future U bend examinations in Units 1 and 2 – Degradation Assessment
- Determine U bend inspection plan for next Unit 1 and Unit 2 outages
- Work with industry to address potential generic implications

PG&E

Requested NRC Actions

- Approve LAR for use of 1.0 POD for R44C45-2H by 3/7/03
- Approve startup and operation of Unit 2 for 120 days
- Review and approve DCPP POPCD for Unit 2 cycle 12 by 6/1/03
- Review pulled tube results and full cycle OA (estimated completion 90 days after startup)

PG&E

NRC Feedback

PG&E

Unit 1 Operability

- Approach with U bends
- Approach for ODSCC
- Conclusion

PG&E

Approach with U bends

- Strategy
  - Determine if Unit 1 bobbin data could be used to detect circumferential defects
  - Review past Unit 2 data to determine growth rate of indications in U bends
  - Determine if Unit 2 condition bounds Unit 1
  - Perform in-situ tests of Unit 2 U bends to determine worst case structural integrity
  - Compare Unit 1 and 2 leakage history

PG&E

Review of Unit 1 Bobbin Data

- Reviewed Unit 2 bobbin and +Point U bend data
  - Bobbin not qualified to detect circumferential flaws
  - Only some of flaws in R5C62 were detectable on re-examination when location known from +Point
  - Reviewed SG 2-1 bobbin data using expanded analyst guidance
  - Called 93 bobbin indications
  - Follow-up +Point of entire SG 2-1 concluded all 93 calls were false
  - Actual SG 2-1 flaws identified with +Point not detectable with bobbin
  - Because of poor detection capability decision was made to inspect 100% of Unit 2 U bends with +Point
- Unit 1 bobbin data review would be inconclusive

PG&E

Review of Past Unit 2 Data

- Although could not use Unit 2 bobbin data to screen for new flaws, tried to use bobbin data to track flaw history
  - With flaw locations identified with +Point, can see some bobbin response when change scale and frequencies
- Decreasing number of bobbin responses visible back several cycles to 2R7
  - Establishes approximate flaw growth rate for Unit 2 U bends
  - Actual crack growth rate should be slower

PG&E

Unit 2 Bounding Unit 1

- Unit 2 Leakage <4 gpd at end of cycle
  - Leakage during cycle 11 varied from about 2 to 6 gpd
  - Leakage during cycle 10 was 1-2 gpd
  - Leakage from R5C62 U bend estimated to be approximately 4 gpd
- Total Unit 1 leakage approximately 1 gpd and stable for last cycle and this cycle
  - If all leakage from a single Unit 1 U bend, flaw opening bounded by Unit 2 leakage
  - Estimated TW crack length of R5C62 about 0.17"

PG&E

Unit 2 U bend In-situ Test

- Performed in-situ test of worst case Unit 2 U bend (R5C62)
  - Did not burst at 3ΔP and met leakage requirements (leakage at SLB ΔP was 0.004 gpm)
  - Meets all performance criteria
  - Demonstrates structural and leakage integrity of tube

PG&E

Unit 1 U bend Conclusion

- Unit 2 condition bounds Unit 1
  - Unit 2 worst case tube meets all performance criteria – Unit 1 will as well
  - Unit 2 worst case tube maintains structural integrity – Unit 1 will as well
  - Unit 1 bobbin data not capable of being used to identify circumferential flaws in U bends

PG&E

Approach for ODSCC

- Determine if Unit 2 bounds Unit 1
- Develop worst case growth rate from Unit 2 and apply to Unit 1
  - Consider both 0.6 POD and POPCD
  - Determine if still meet POB and leakage limits at end of cycle

PG&E

Unit 2 Bounding Unit 1

- Reviewed 1R11 eddy current data
  - Determined that Unit 1 ODSCC crack growth rate is >1 cycle behind Unit 2 growth rates
  - Number of Unit 1 (EOC 11) as-found and large flaws less than Unit 2 (EOC 10) (420/2 for Unit 1 vs. 493/14 for Unit 2)
- Unit 2 EOC 10 VDG analysis more pronounced than Unit 1 EOC 11
- Unit 2 has experienced greater saltwater in leakage from condenser than Unit 1

PG&E

Unit 2 Worst Case Growth Rate

- Developed a VDG based on SG 2-4 (worst of Unit 2 SGs)
- Applied Unit 2 SG 2-4 VDG to Unit 1
  - Calculation with POPCD, POB and leakage below limits for cycle
  - Calculation with 0.6 POD with 21.5V flaw included in growth, POB and leakage below limits through 1.4EFPY (approx 12/25/03)

PG&E

Locked Tube Support Plates

- Although not NRC approved, tube pull force data and analysis of SLB loads indicate tubes are locked into TSPs (WCAP-14707) as presented earlier
- Tubes not expected to displace during steam line break – no tube burst and limited leakage expected during event

PG&E

ODSCC Conclusion

- Unit 2 ODSCC growth rates are worse than Unit 1 (approx 1 cycle behind)
- Applied worst case growth from Unit 2 to Unit 1
  - POPCD indicates full cycle operation
  - 0.6 POD indicates operation through 1.4 EFPY
- TSPs are locked, minimizing potential for burst and leakage

PG&E