Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

JUN 14 2002

10 CFR 50.4

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555

Gentlemen:

In the Matter of	)	Docket No.50-390
Tennessee Valley Authority	)	

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1 - STEAM GENERATOR VOLTAGE BASED ALTERNATE REPAIR CRITERIA FOR AXIAL OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC) - CYCLE 4 NINETY DAY REPORT

The purpose of this letter is to provide NRC the Axial ODSCC Cycle 4 ninety-day report entitled "Condition Monitoring and Operational Assessment: GL-95-05 Alternate Repair Criterion End of Cycle 4." This report demonstrates that the Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," acceptance criteria is satisfied at the end of the Unit 1 Cycle 4 refueling outage. This report also demonstrates that the Generic Letter 95-05 acceptance criteria is satisfied throughout Unit 1 Cycle 5. TVA committed to provide this report in TVA's April 10, 2000 letter concerning the license amendment request (WBN-TS-99-14) for the subject alternate repair criteria. TVA implemented the alternate repair criteria during the Unit 1 Cycle 4 refueling outage. Enclosure 1 provides this ninety-day report.

As requested during the steam generator outage teleconference with NRC staff, the methodology TVA utilized for the operational assessment for top of tubesheet circumferential ODSCC discovered during the Unit 1 Cycle 4 refueling outage is provided in Enclosure 2.

D030

JUN 14 2002

If you have any questions concerning this report, please contact me at (423) 365-1824.

Sincerely,

P. L. Pace
Manager, Site Licensing
and Industry Affairs

Enclosures
cc (Enclosures):

NRC Resident Inspector
Watts Bar Nuclear Plant
1260 Nuclear Plant Road
Spring City, Tennessee 37381

Mr. L. Mark Padovan, Senior Project Manager
U.S. Nuclear Regulatory Commission
MS 08G9
One White Flint North
11555 Rockville Pike
Rockville, Maryland 20852-2738

U.S. Nuclear Regulatory Commission
Region II
Sam Nunn Atlanta Federal Center
61 Forsyth St., SW, Suite 23T85
Atlanta, Georgia 30303

ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNIT 1
CONDITION MONITORING AND OPERATIONAL ASSESSMENT
GL 95-05 VOLTAGE BASED ALTERNATE REPAIR CRITERIA
END OF CYCLE 4

90 DAY REPORT

Tennessee Valley Authority

Condition Monitoring and Operational Assessment: GL-95-05 Alternate Repair Criterion End of Cycle 4

90 Day Report

Watts Bar Unit 1

Report Number SG-SGDA-02-13

FINAL REPORT
May, 2002

Authors Names	Signature / Date	For Pages
D.J. Ayres	5/14/02	All
Verifier's Name	Signature / Date	For Pages
V. Srinivas	5/14/02	All
Manager Name	Signature / Date	
R.J. Sterdis	5/14/02	

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0.0 Glossary of Acronyms

BOC Beginning of operation cycle. The current inspection is just prior to BOC-5.

EOC End of operation cycle. The current inspection is at EOC-4. The prior inspection results are from EOC-3. The end of the next cycle is EOC-5

POD Probability of detection. This value is set equal to 0.60 for the GL-95-05 predictive analysis for the condition of the steam generators at the end of the next cycle.

ODSCC Outside diameter stress corrosion cracking

SG Steam Generator identifier. Specifically SG 1, SG 2, SG3 and SG 4.

TSP Tube support plate. The Generic letter 95-05 Alternate Repair Criterion applies to ODSCC in the tubes at the TSPs

1.0 Introduction

Watts Bar Unit 1 completed the Cycle 4 of operation and subsequent steam generator tube inspection in March, 2002. Axial ODSCC has been confirmed within the TSP regions of the steam generators and is a current degradation mechanism at Watts Bar Unit 1. The alternate repair criterion (ARC) defined in NRC Generic Letter 95-05 (Reference 1) is being implemented at Watts Bar Unit 1 for the first time. This report provides a condition monitoring assessment that demonstrates that the GL-95-05 acceptance criteria are satisfied at the end of operational Cycle 4 (EOC-4), and an operational assessment that demonstrates that the GL-95-05 acceptance criteria will continue to be satisfied throughout operational Cycle 5. A bounding growth rate was used in the EOC-5 prediction.

The operation cycle just completed, Cycle 4, was 486 Effective Full Power Days (EFPD). The next cycle, Cycle 5 is estimated to be 533 EFPD.

2.0 Summary and Conclusions

Bobbin voltage indications of ODSCC at the tube support plates were detected and measured in all four steam generators. Based on this voltage distribution, using the methodology of References 1 and 2, a Condition Monitoring evaluation including the computation of the probability of tube burst (POB) and the amount of leakage predicted for steam line break conditions at EOC-4 was performed. The acceptance criteria on POB and leakage are satisfied with significant margin.

The change in voltage from the previous inspection was determined by historical review for each indication detected. The apparent voltage growth rate per EFPY during Cycle 4 is not well defined because of the small number of indications identified. In order to perform the prediction for the EOC-5 voltage distribution a bounding growth rate distribution based on data from other similar plants was used. The conservative growth distribution envelopes all plants with ¾ inch tubes when a one-volt repair criterion was in effect. The large growth rates observed in these plants occurred after the indications were left in service for many cycles and are not representative of the early stage of growth at Watts Bar. This distribution was developed in Reference 3. An operational assessment prediction of the POB and leakage at steam line break conditions at EOC-5 was performed using the conservative bounding growth rate. The results indicate that the acceptance criteria on POB and leakage at EOC-5 will be satisfied with acceptable margin. Therefore the Reference 1 acceptance criteria will be satisfied throughout Cycle 5.

3.0 EOC-4 Inspection Results

3.1 Voltage Distributions at EOC-4

A summary of eddy current signal voltage distributions at the drilled support plates for all steam generators is shown in Tables 3.1 through 3.4 for steam generators 1 through 4 respectively. The detailed indication list is presented in Appendix A. Tables 3.1 through 3.4 show the number of indications in each voltage range detected at EOC-4, and the number of indications removed from service due to tube repairs for any reason. The number of indications that remain in service for Cycle 5 is the difference between the number detected and the ones removed from service. No tubes were unplugged with the intent to return them to service after inspection. The number of indications confirmed by rotating pancake coil (RPC) or not inspected is also given in Tables 3.1 through 3.4. Appendix A shows for each indication if it was confirmed or not tested.

The summary of all four steam generators shows the following:

- A total of 152 bobbin signals were identified as ODSCC TSP indications during the inspection.
- Of the 152 indications, 21 were above 1 volt. All indications were below the structural limit of 4.88 volts specified in Reference 7.
- Of the 21 indications above 1 volt, 10 indications were plugged and 11 indications were tested by RPC and were not confirmed, and therefore left in service.
- 3 indications were removed from service for reasons other than ODSCC at the support plates.

Table 3.1
Inspection Results for SG 1

Voltage Bin	CY 4 Inservice	Tested and not confirmed	Indications Repaired	Returned to Service CY 5
0.1	0			0
0.2	2			2
0.3	4			4
0.4	9			9
0.5	13		1	12
0.6	7			7
0.7	3			3
0.8	5		1	4
0.9	2			2
1	0			0
1.1	2	1	1	1
1.2	1		1	
1.3	3		3	
1.4				
1.5				
1.6				
1.7			1	
1.8	1			
1.9				
2	1		1	
2.1				
....				
2.8	1		1	
TOTAL	54	1	10	44

Figure 3.1

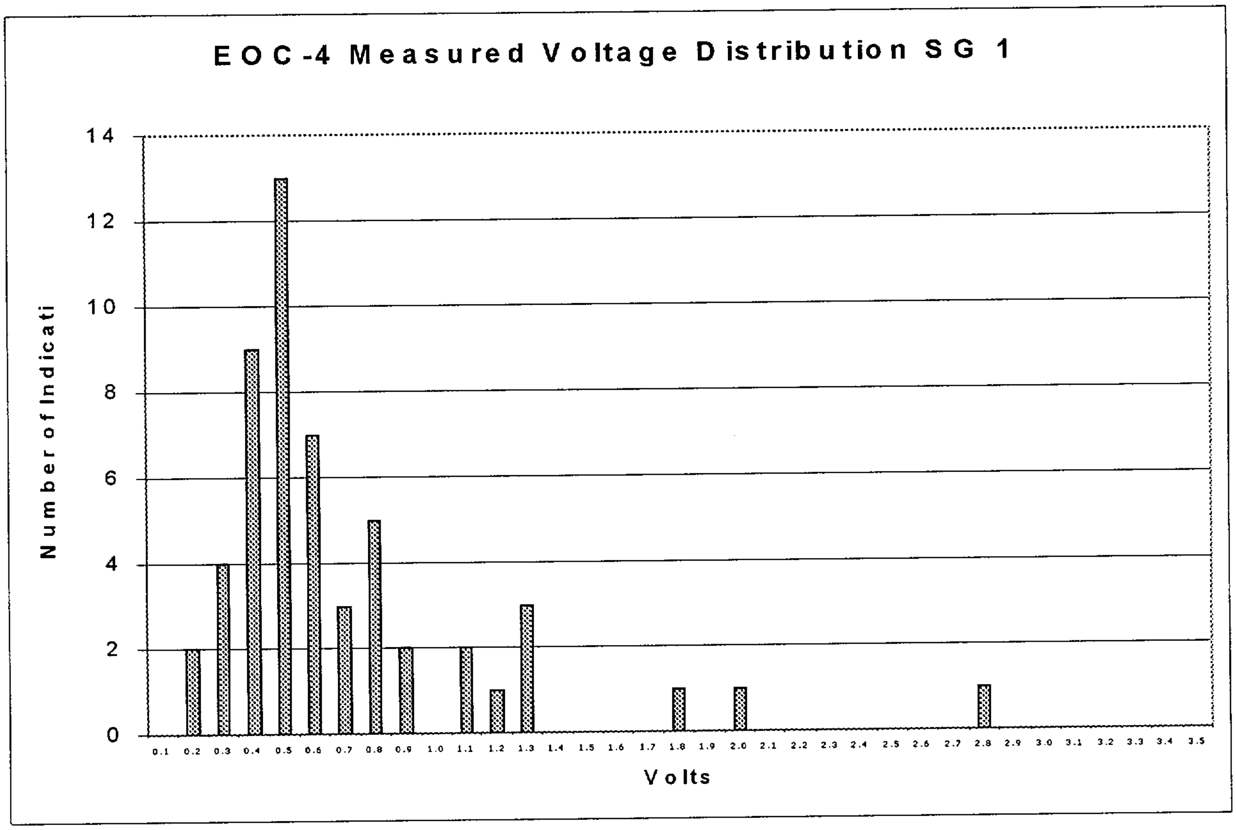


Figure 3.2

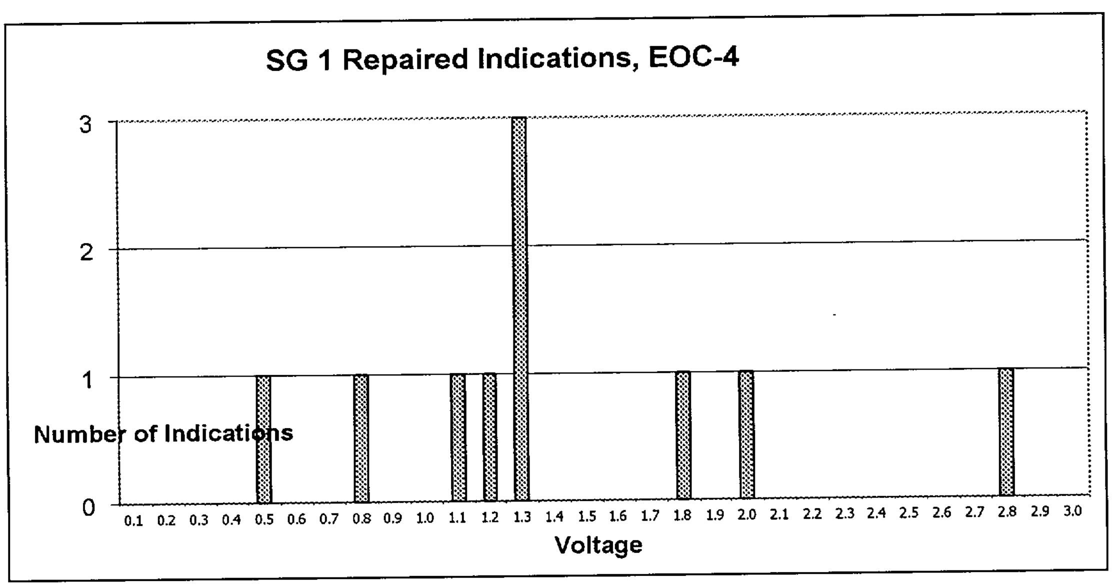


Table 3.2
Inspection Results for SG 2

Voltage Bin	CY 4 Inservice	Tested and not confirmed	Indications Repaired	Returned to Service CY 5
0.1	0			0
0.2	0			
0.3	3			3
0.4	5			5
0.5	2			2
0.6	4			4
0.7	5			5
0.8	3			3
0.9	0			0
1	1			1
1.1	0			0
1.2	1	1		1
1.3	1	1		1
1.4	2	2		2
1.5	1	1		1
1.6				
1.7				
1.8				
1.9				
2				
TOTAL	28	5	0	28

Figure 3.3

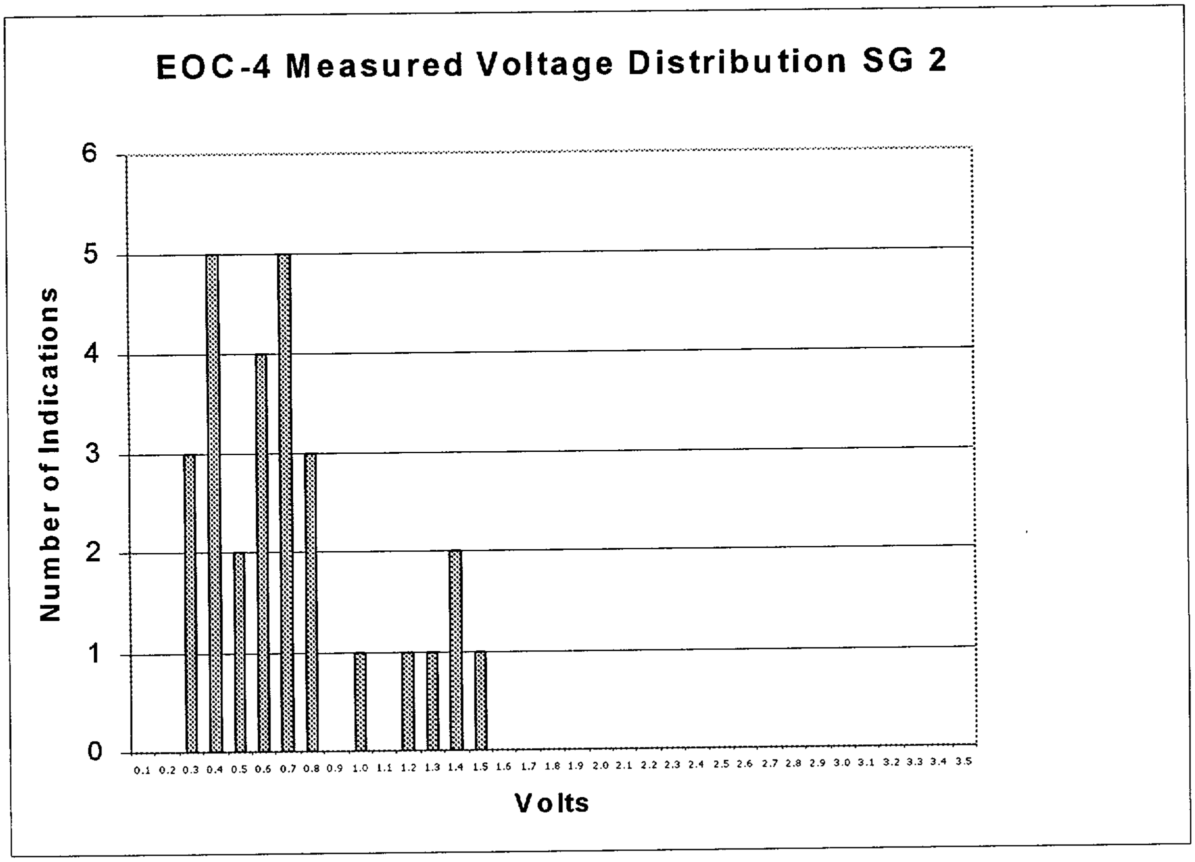

EOC-4 Measured Voltage Distribution SG 2
Number of Indications
6
5
4
3
2
1
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5
Volts

Table 3.3
Inspection Results for SG 3

Voltage Bin	CY 4 Inservice	Tested and not confirmed	Indications Repaired	Returned to Service CY 5
0.1	0			0
0.2	2			2
0.3	4			4
0.4	3			3
0.5	9			9
0.6	4			4
0.7	3			3
0.8	2			2
0.9	2			2
1	1			1
1.1	1		1	
1.2				
1.3				
1.4				
1.5				
1.6				
1.7				
1.8				
1.9				
2				
TOTAL	31	0	1	30

Figure 3.4

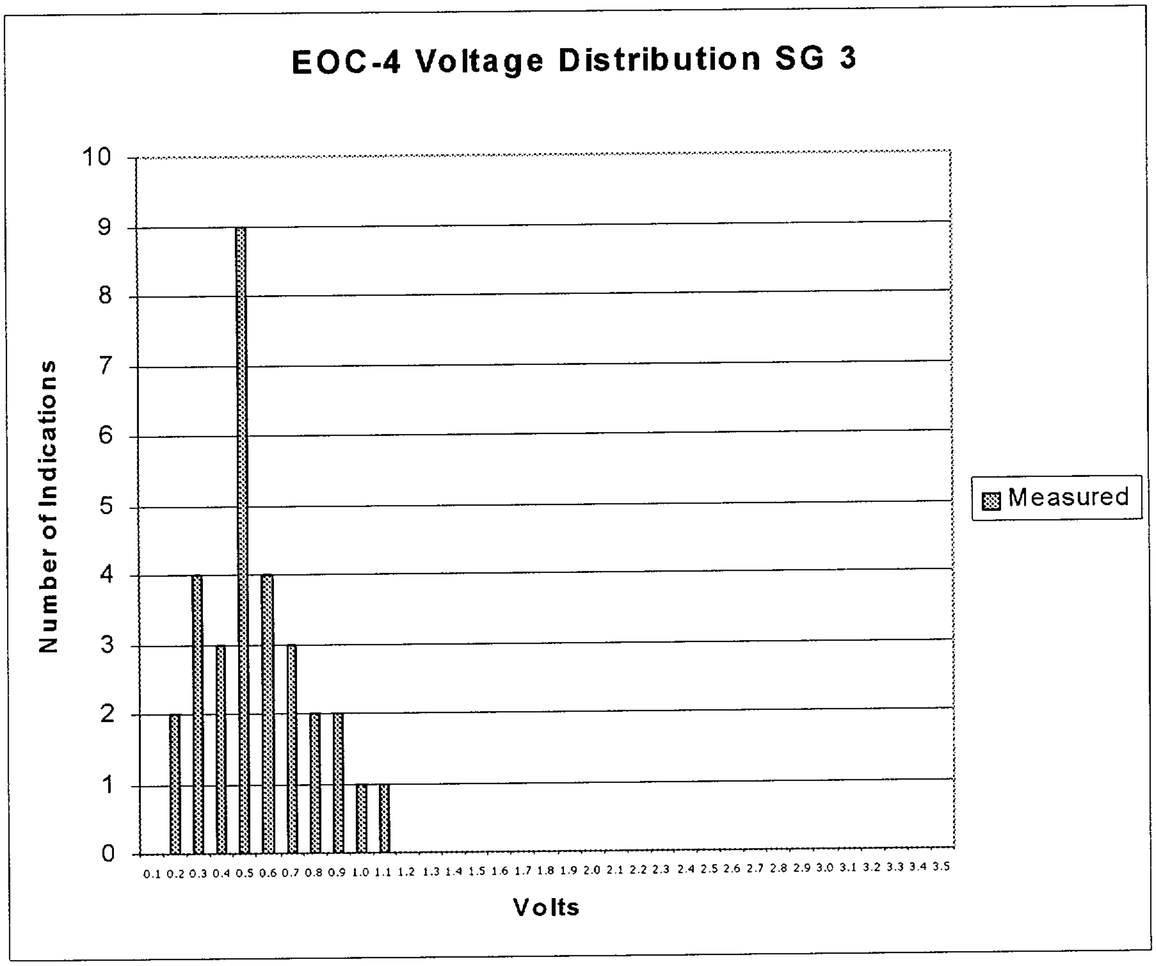


Figure 3.5

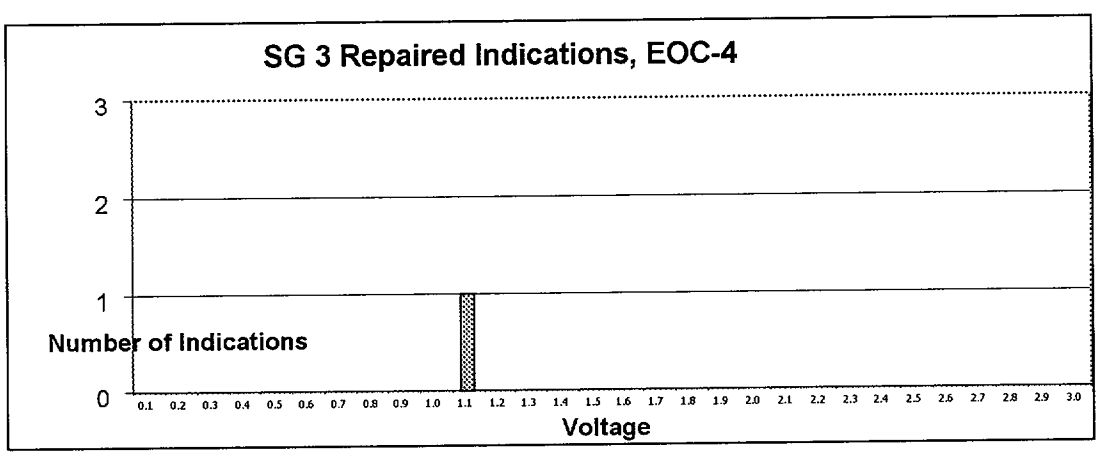


Table 3.4
Inspection Results for SG 4

Voltage Bin	CY 4 Inservice	Tested and not confirmed	Indications Repaired	Returned to Service CY 5
0.1	0			0
0.2	0			0
0.3	3			3
0.4	4			4
0.5	12			12
0.6	4			4
0.7	4			4
0.8	2			2
0.9	2		1	1
1	2			2
1.1	0			0
1.2	5	4	1	4
1.3	0			0
1.4	1	1		1
1.5				
1.6				
1.7				
1.8				
1.9				
2				
TOTAL	39	5	2	37

Figure 3.6

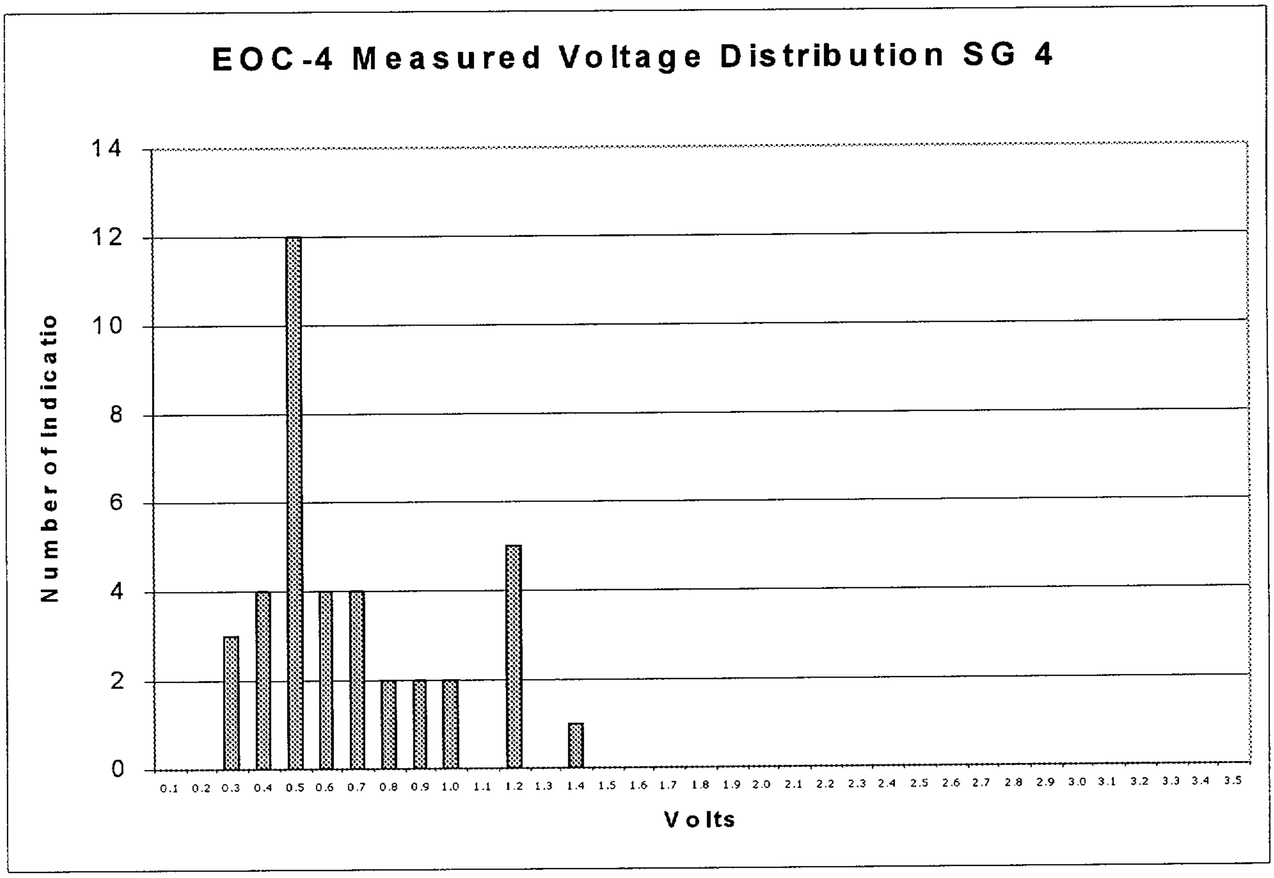
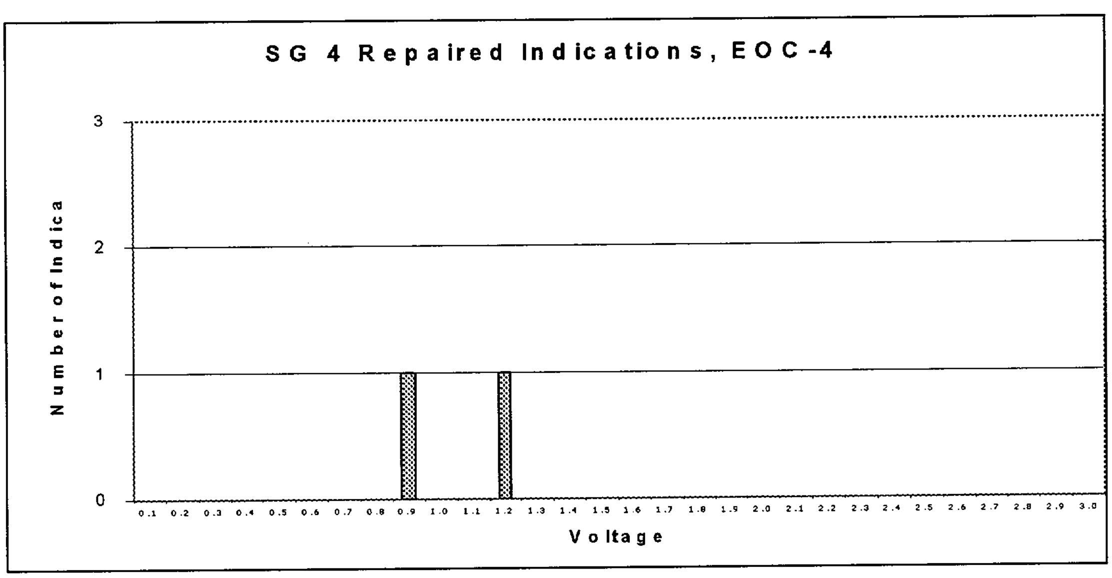


Figure 3.7



3.2 Voltage Growth Rates for Cycle 4

The measured voltage growth for each indication detected at EOC-4 was determined by identifying the corresponding voltage at the previous inspection, EOC-3. The following process was used to determine the EOC-3 voltage:

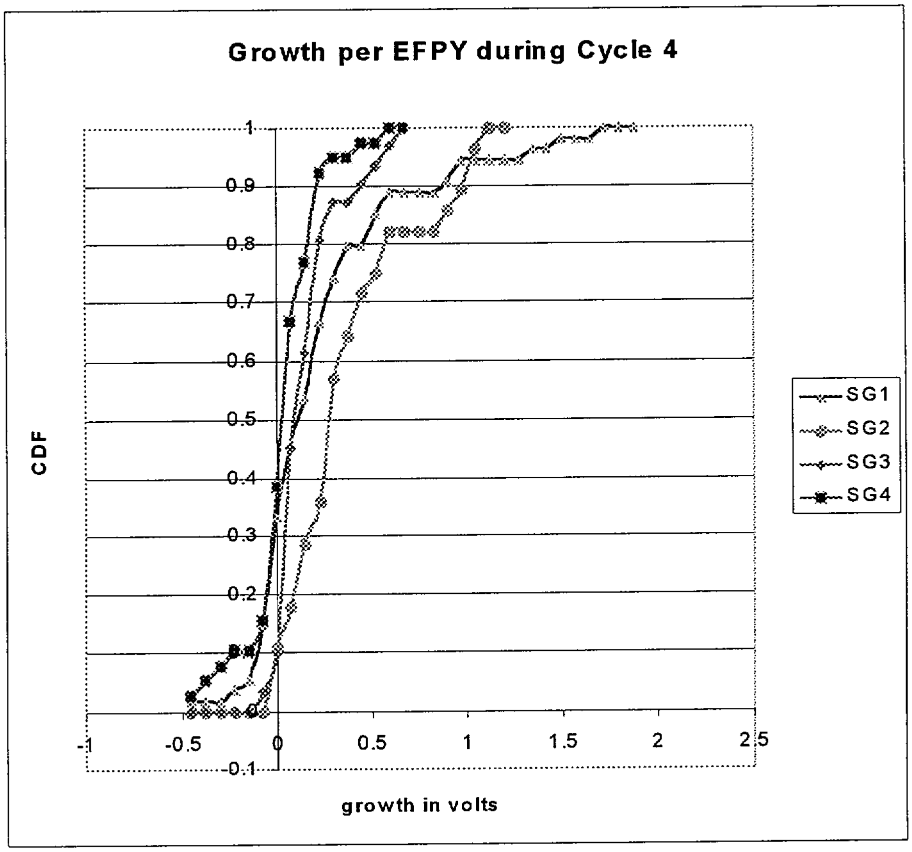
The voltage at EOC-3 is provided for each indication detected at EOC-4 in Appendix A. The procedure for computing the voltage change and binning the values is described in Reference 4. The binned voltage differences for each steam generator are shown in Table 3.5.

Table 3.5
Voltage Changes from EOC-3 to EOC-4
Number of Indications

Voltage Bin	SG 1	SG 2	SG 3	SG 4
-0.6	1	0	0	1
-0.5	0	0	0	1
-0.4	0	0	0	1
-0.3	1	0	0	1
-0.2	1	0	0	0
-0.1	5	0	1	2
0	10	3	11	9
0.1	7	2	5	11
0.2	4	3	6	4
0.3	7	2	2	6
0.4	4	6	0	1
0.5	3	2	1	0
0.6	0	2	1	1
0.7	3	1	1	0
0.8	2	2	1	1
0.9			1	
1				
1.1				
1.2	1	1		
1.3	2	1		
1.4		2		
1.5		1		
1.6				
1.7				
1.8	1			
1.9				
2.0	1			
2.1				
2.2				
2.3	1			

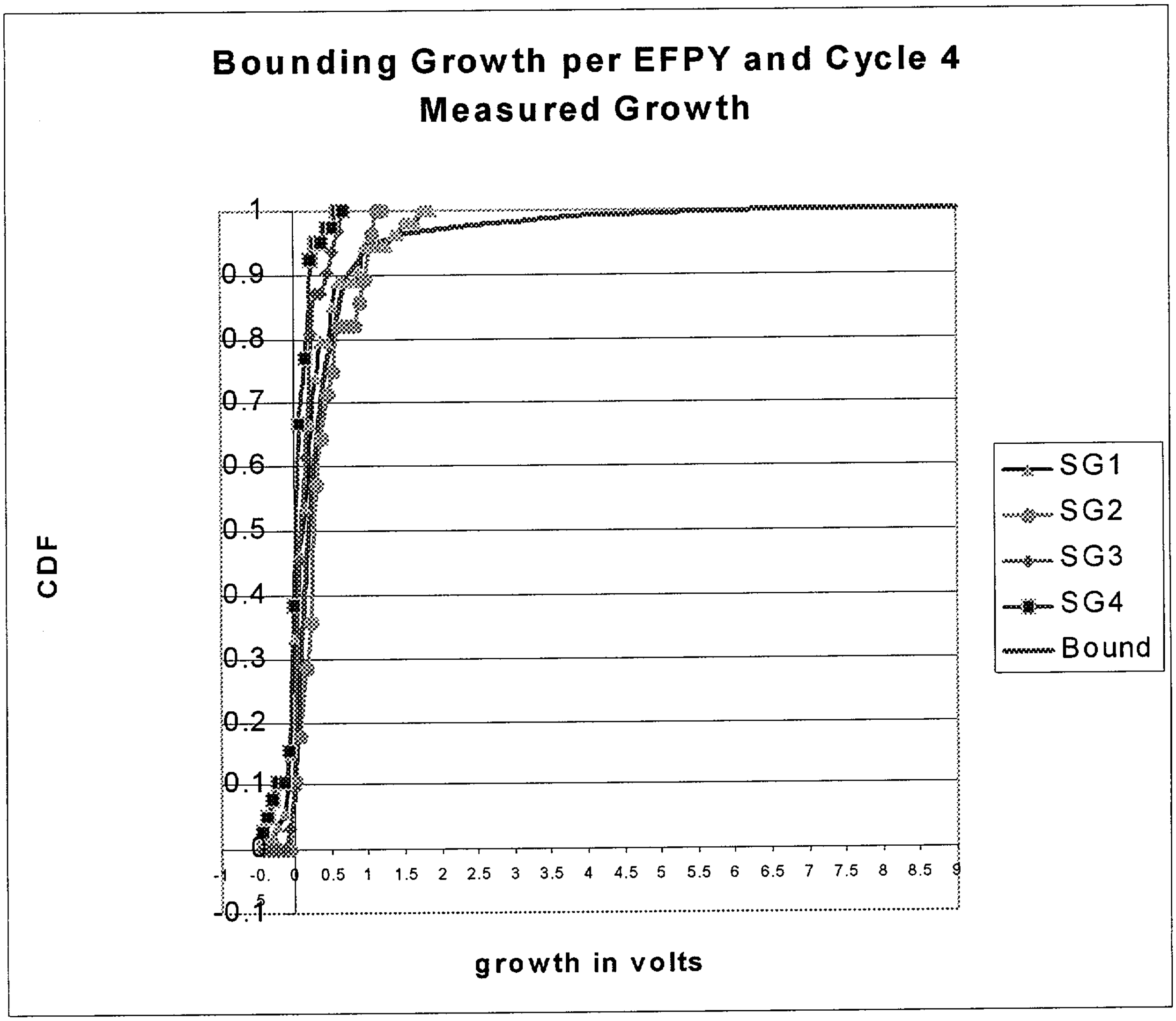
The distribution of voltage differences scaled to 365 EFPD from the cycle 4 length of 486 EFPD is shown in Figure 3.8 for all four steam generators. The irregularities in the cumulative distribution factor (CDF) are due to the small number of indications identified.

Figure 3.8



In order to conservatively represent the voltage growth, a bounding cumulative distribution was developed based on all plants with ¾ inch tubes when a one-volt repair criterion was in effect. This growth rate is documented in Reference 3, and shown along with the data of Figure 3.8 in Figure 3.9

Figure 3.9



This bounding growth rate will be used in the predictions for EOC- 5.

4.0 Analysis Methods and Data Base for ARC Correlations

Westinghouse has developed a Monte Carlo based computer program to perform the calculations prescribed in GL 95-05 (Reference 1). The methodology for predicting the EOC voltage distribution and computing the probability of burst and leakage at accident conditions is based on the Westinghouse Topical Report, WCAP-14277, Revision 1 (Reference 2). The specific computer program employed is described and verified in Reference 5.

The current data for burst and leakage correlations are included in Addendum 3 (Reference 6) and Addendum 4 (Reference 7) to EPRI Report NP-7480-L. The specific parameters used in the correlations are provided in Sections 4.1 through 4.4.

4.1 Tube Material Properties

The tube material properties are provided in Reference 7 for 3/4 inch diameter tubes at 650F. The parameters used in the analysis are the flow stress mean of 71.565 Ksi and the flow stress standard deviation of 3.567 Ksi.

4.2 Burst Correlation

The burst pressure, Pb, is normalized to a material with a flow stress of 71.565 ksi ,that is the mean of the 3/4 inch tube data appropriate for Watts Bar Unit 1. The correlation parameters are taken from Reference 7.

$$Pb = a0 + a1\ Log(Volts)$$

Parameter	Addendum 4 Database
a0	7.4580 Ksi
a1	-2.95399
Standard error	0.89631
Number of data points	99
Reference Flow Stress	71.565 Ksi
Covariance Coefficient V11	0.011289
Covariance Coefficient V12	-0.0081539
Covariance Coefficient V22	0.020967

4.3 Leak Rate Correlation

The leak rate criterion is given in terms of gallons per minute condensed at room temperature. The correlation formula provides leak rate in liter per hour at a pressure of 2405 psi. In order to obtain gallons per minute condensed at room temperature the leak rate Q in the correlation equation must be multiplied by the conversion factor 0.004403. Addendum 4 did not change the leak rate correlation.

$$\text{Log}(Q) = b3 + b4\ \text{Log}(\text{Volts})$$

Parameter	Addendum 3 Database
b3	-1.870836
b4	2.976689
Standard error	0.597912
Number of data points	48
Covariance Coefficient V11	0.104184
Covariance Coefficient V12	-0.105033
Covariance Coefficient V22	0.114041

4.4 Probability of Leak Correlation

The probability of leak as a function of indication voltage is taken from Reference 7. In the Monte Carlo analysis leakage is quantified only if the indication is computed be a leaker, based on the probability of leak correlation.

$$Pr(Leak) = 1/\{1+ e^{[b1 + b2 \, Log(Volts)]}\}$$

Parameter	Addendum 4 Database
b1	-4.8271
b2	8.4489
Number of data points	126
Covariance Coefficient V11	1.1622
Covariance Coefficient V12	-1.7092
Covariance Coefficient V22	2.8752

4.5 NDE Uncertainties

The NDE uncertainties applied for the EOC-4 and EOC-5 voltage projections are the same as given in the prior Sequoyah Unit 1 90 Day reports. The probe wear uncertainty has a standard deviation of 7% about a mean of zero and has a cutoff at 15% based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are used in the Monte Carlo analysis to predict the burst probabilities and accident leak rates at EOC-4, and EOC-5. The voltages reported were adjusted to account for differences between the laboratory standard and the standard used in the field.

5.0 Condition Monitoring: Tube Leak Rate and Burst Probabilities at EOC-4

5.1 Analysis Approach

The measured EOC-4 voltage distributions of Table 3.1 through 3.4 for each steam generator are used as the basis for the leak rate and burst probability predictions for EOC-4. The voltage distributions developed for the computation of POB and leakage consider NDE uncertainty on the measured values, but consider no voltage growth.

5.2 EOC-4 Burst Probabilities and Leak Rates

The Monte Carlo analysis results for each of the steam generators based on the measured voltage distribution at EOC-4 are shown in Table 5.1. The analysis program inputs and outputs are detailed in Reference 4. Two hundred and fifty thousand Monte Carlo trials were performed for each steam generator. The leakage rate is the 95^{th} percentile evaluated at 95% confidence. The burst probability is 95% confidence based on the number of trials.

Table 5.1
Analysis Results for Measured EOC-4 Voltage Distributions

SG	Number of Monte Carlo Trials	Number of Indications	Number of Bursts in 250,000 Trials	Max Volts, Measured	Burst Probability 95% conf.	95/95 SLB Leak Rate, gpm
1	250,000	54	13	2.76	8.3 x 10^-5	0.0075
2	250,000	28	0	1.43	1.2 x 10^-5	0.00056
3	250,000	31	0	1.07	1.2 x 10^-5	0.000054
4	250,000	39	1	1.33	1.9 x 10^-5	0.00042

5.3 Comparison with Acceptance Criteria

All steam generators are well below the burst acceptance criterion of 1.0 x 10^-2, and the Watts Bar Unit 1 leakage criterion of 1.0 gpm. The acceptance criteria on POB and leakage are satisfied with significant margin.

6.0 Operational Assessment: Tube Leak Rate and Burst Probabilities at EOC-5

6.1 Analysis Approach

The BOC-5 voltage distribution is developed from the measured distribution by considering the POD and the indications that are removed from service. The EOC-5 voltage distribution is developed considering the NDE uncertainties and voltage growth during the cycle. The latest burst and leakage correlations, Reference 7, are used for the EOC-5 predictions. The burst probabilities and leak rates are computed using the computed EOC-5 voltage predictions to address the acceptance criteria at the end of the cycle.

6.2 BOC Voltage Distribution

The BOC-5 voltage distribution for each steam generator is determined from the measured EOC-4 voltage distribution. First, the number of indications potentially missed during the inspection and the number of new indications initiating during the Cycle 5, is considered by dividing the measured number of indications in each voltage range by the assumed POD. From this number of indications in each voltage range is subtracted the number of indications removed from service for any reason. This then gives the BOC-5 voltage distribution.

6.2.1 POD

The POD used is the NRC accepted value of 0.6 for all voltages (Reference 1).

6.2.2 Tube Repairs

Considering the repaired tubes and the POD, the BOC-5 voltage distribution for each SG is given in Table 6.1

Table 6.1
BOC-5 Voltage Distributions for all SGs

Voltage Bin	SG 1	SG 2	SG 3	SG 4
0.1	0	0	0	0
0.2	3.33	0	3.33	0
0.3	6.67	5.00	6.67	5.00
0.4	15.00	8.33	5.00	6.67
0.5	20.67	3.33	15.00	20.00
0.6	11.67	6.67	6.67	6.67
0.7	5.00	8.33	5.00	6.67
0.8	7.33	5.00	3.33	3.33
0.9	3.33	0	3.33	2.33
1	0	1.67	1.67	3.33
1.1	2.33	0	0.67	0
1.2	0.67	1.67	0	7.33
1.3	2.00	1.67	0	0
1.4	0	3.33	0	1.67
1.5	0	1.67	0	0
1.6	0	0	0	0
1.7	0	0	0	0
1.8	0.67	0	0	0
1.9	0	0	0	0
2	0.67	0	0	0
2.1	0	0	0	0
2.2	0	0	0	0
2.3	0	0	0	0
2.4	0	0	0	0
2.5	0	0	0	0
2.6	0	0	0	0
2.7	0	0	0	0
2.8	0.67	0	0	0
TOTAL	80.00	46.67	50.67	63.00

6.3 Voltage Growth Rates for Cycle 5

The bounding growth distribution in terms of volt change per EFPY is shown in Figure 3.9 and listed in Table 6.2. This growth rate is developed in Reference 3.

Table 6.2
Cumulative Distribution of Bounding Voltage Growth per EFPY for EOC-5 Predictions

Voltage Growth per EFPY	Cumulation
0.0	0.0782
0.1	0.3536
0.2	0.5100
0.3	0.6290
0.4	0.7225
0.5	0.7902
0.6	0.8401
0.7	0.8836
0.8	0.9099
0.9	0.9264
1.0	0.9408
1.1	0.9478
1.2	0.9525
1.4	0.9581
1.6	0.9645
1.9	0.9696
2.4	0.9763
3.6	0.9874
4.4	0.9930
6.2	0.9986
9	1.0

6.4 Prediction of Voltage Distributions at EOC-5

Using the number of BOC indications from Table 6.1 and the growth distribution from Table 6.2, the prediction of the EOC-5 voltage distribution is made for each steam generator. The length of Cycle 5 is presumed to be 533 effective full power days (EFPD). These distributions are shown for each steam generator in Figures 6.1 through 6.4. The analysis inputs and outputs are detailed in Reference 4.

Figure 6.1

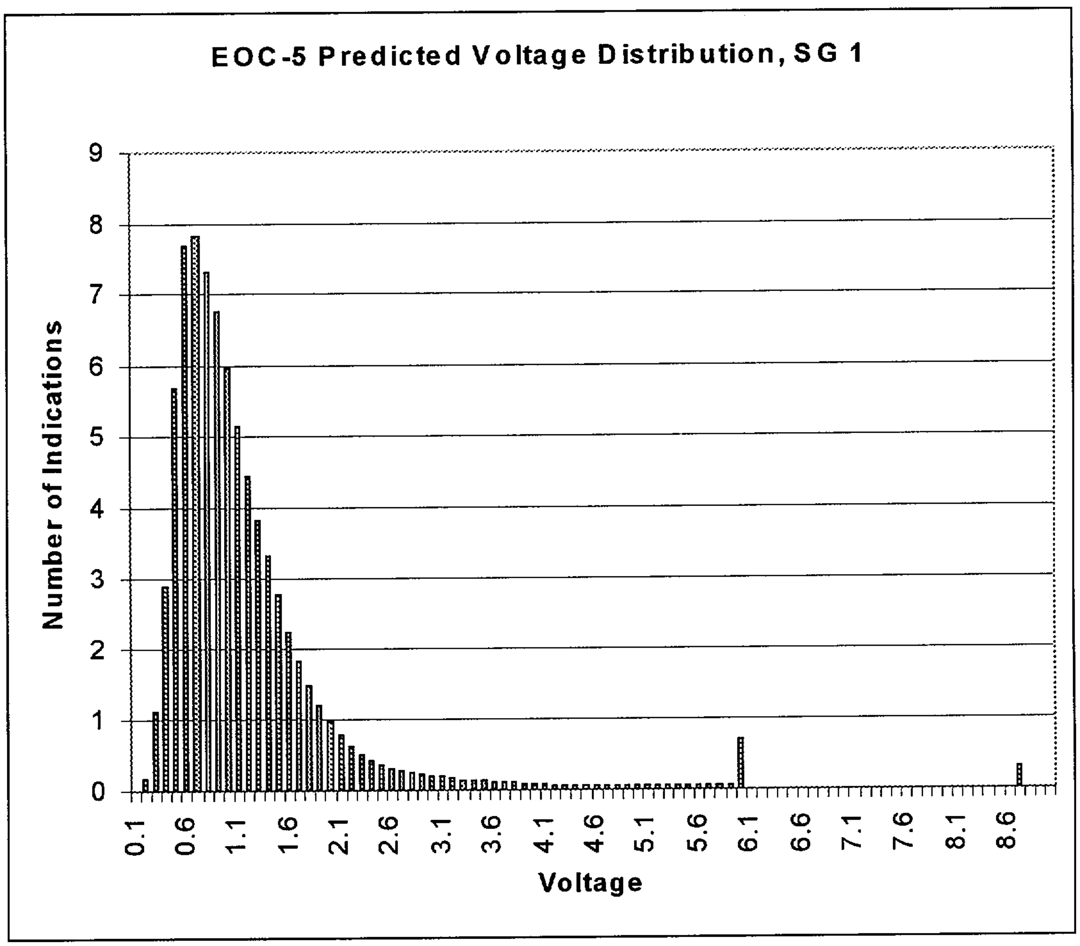


Figure 6.2

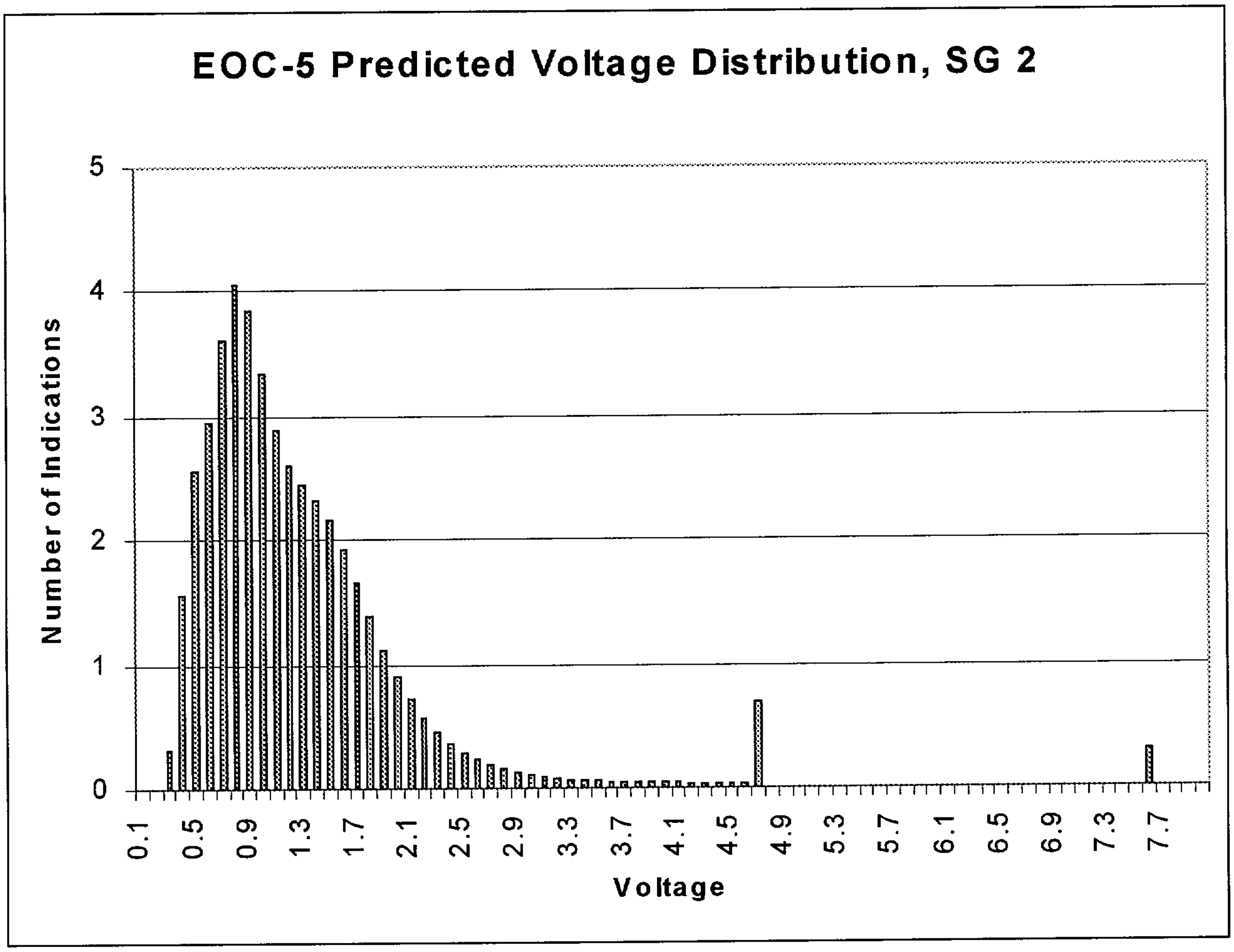

EOC-5 Predicted Voltage Distribution, SG 2
Number of Indications
0
1
2
3
4
5
Voltage
0.1
0.5
0.9
1.3
1.7
2.1
2.5
2.9
3.3
3.7
4.1
4.5
4.9
5.3
5.7
6.1
6.5
6.9
7.3
7.7

Figure 6.3

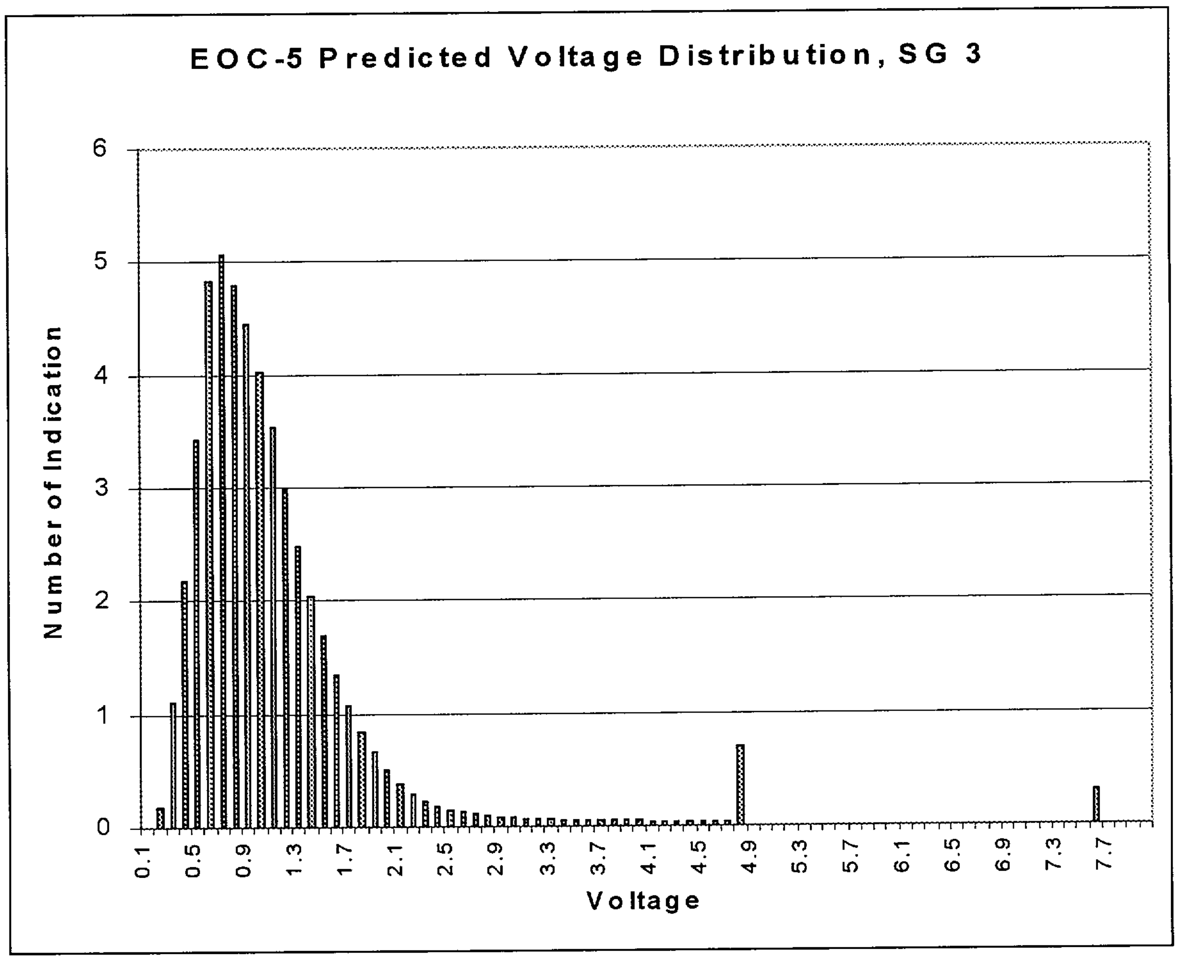
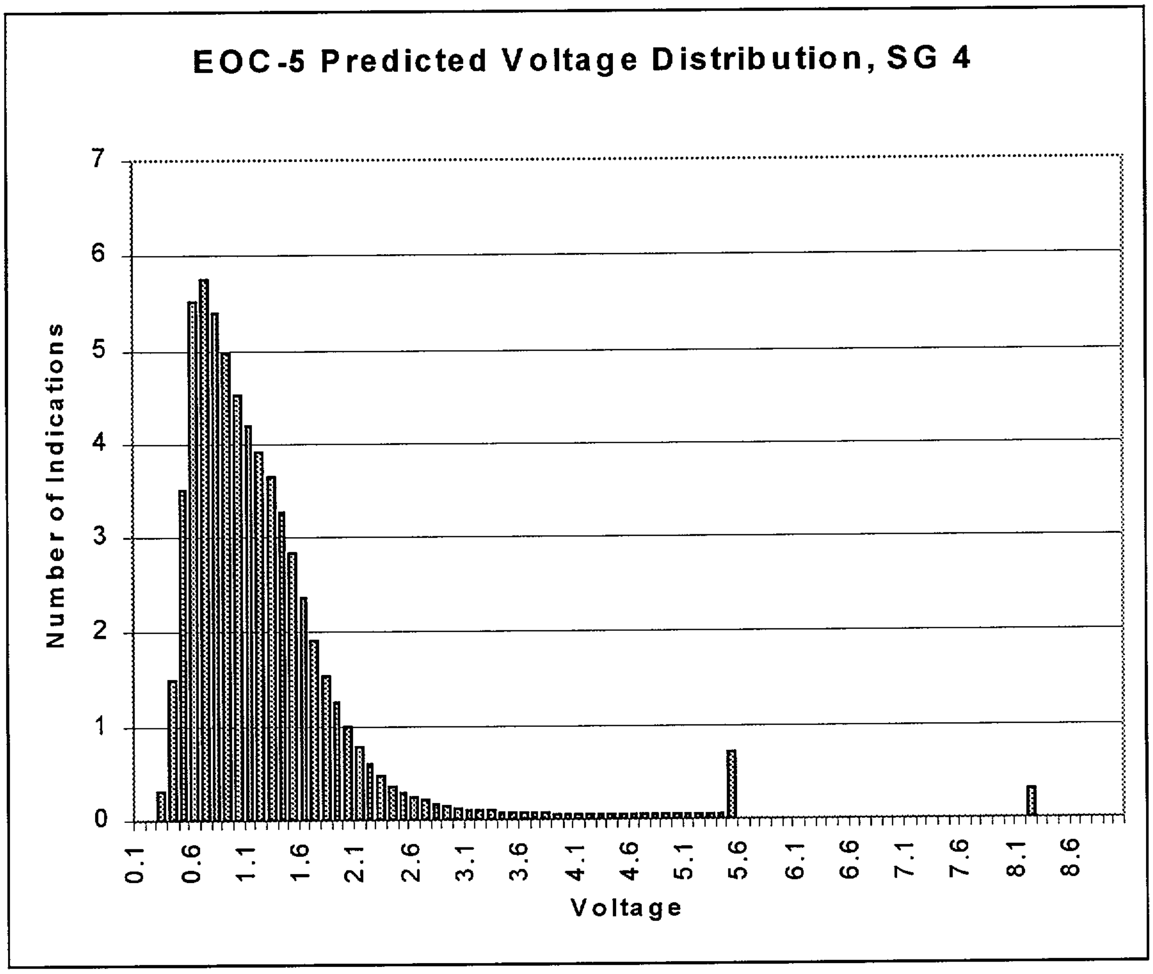

EOC-5 Predicted Voltage Distribution, SG 3
Number of Indication
0
1
2
3
4
5
6
0.1
0.5
0.9
1.3
1.7
2.1
2.5
2.9
3.3
3.7
4.1
4.5
4.9
5.3
5.7
6.1
6.5
6.9
7.3
7.7
Voltage

Figure 6.4


EOC-5 Predicted Voltage Distribution, SG 4
Number of Indications
0
1
2
3
4
5
6
7
0.1
0.6
1.1
1.6
2.1
2.6
3.1
3.6
4.1
4.6
5.1
5.6
6.1
6.6
7.1
7.6
8.1
8.6
Voltage

6.5 Prediction of Tube Leak Rates and Burst Probabilities at EOC-5

The Monte Carlo analysis results for predicted EOC-5 voltage distributions are shown in Table 6.3. Two hundred and fifty thousand Monte Carlo trials were performed for each steam generator in this operational assessment. The leakage rate is the 95th percentile evaluated at 95% confidence. The burst probability is 95% confidence based on the number of trials. The analysis program inputs and outputs are detailed in Reference 4.

Table 6.3
EOC-5 Predicted Results

SG	Number of Monte Carlo Trials	Number of Indications	Number of Bursts in 250,000 Trials	Max Volts	Burst Probability 95% conf.	95/95 SLB Leak Rate, gpm
1	250,000	80.00	1919	8.7	7.79 x 10^-3	0.419
2	250,000	46.67	1200	7.6	5.03 x 10^-3	0.270
3	250,000	50.67	1207	7.6	5.06 x 10^-3	0.267
4	250,000	63.00	1521	8.2	6.34 x 10^-3	0.345

Note: The maximum voltage is defined as the voltage where the integration of the voltage distribution from the tail reaches 0.3 of an indication

The high maximum voltage values predicted are a consequence of the bounding growth rate. It is expected that the POB and leakage predictions are very conservative due to the use of this bounding growth rate.

6.6 Comparison with Acceptance Criteria

All steam generators are below the burst acceptance criterion of 1.0 x 10^-2, and the Watts Bar Unit 1 leakage criterion of 1.0 gpm. It is expected that the condition monitoring analysis at the next inspection will result in significantly more margin than can be demonstrated using the bounding growth rate.

7.0 References

1. NRC Generic Letter 95-05. "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking", USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

2. WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections," Westinghouse Nuclear Services Division, December 1996.

3. Westinghouse Calculation Note, CN-SGDA-02-85, " Bounding Growth Distribution for Axial ODSCC Indications in ¾" Tubes", May, 2002

4. Westinghouse Calculation CN-SGDA-02-101, Rev. 0, " Calculation Details for GL 95-05 Analyses for Watts Bar Unit 1 End of Cycle 4", May, 2002

5. ABB CENP Report, 00-TR-FSW-006, Rev. 0, " GL 95-05 Analysis Methods for Sequoyah Unit 1", February 22, 2000

6. EPRI Report NP-7480-L, Addendum 3, 1999 Database Update, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Criteria," May 1999

7. EPRI Report NP-7480-L, Addendum 4, 2001 Database Update , "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Criteria," March 2001

Appendix A

Indication List
Watts Bar Unit 1 GL-95-05
End of Cycle 4
Notes
C: RPC tested and confirmed
NC: RPC tested and not confirmed
NT: Not RPC tested

SG 1

Row	Col	Supt	EOC-4 Volts	EOC-3 Volts	EOC-4 Cal	Tested?	Plugged?
3	46	H03	0.81	0.59	57 H		
3	52	H02	0.76	0.33	57 H		
3	74	H03	0.33	0.36	71 H		
4	28	H02	0.36	0.29	73 H		
4	62	H03	0.57	0.58	71 H		
4	88	H03	0.35	1.03	71 H		
5	9	H03	0.77	0.4	73 H		
5	11	H03	0.43	0.3	73 H		
5	61	H03	0.38	0.38	73 H		
5	63	H03	0.46	0.24	73 H		
5	95	H02	1.3	0.5	57 H	C	P
5	95	H03	0.45	0.78	57 H		P
6	20	H02	1.79	0.01	73 H	C	P
6	20	H03	1.23	0.01	73 H	C	P
6	42	H03	2.76	0.51	57 H	C	P
6	60	H03	0.38	0.44	71 H		
6	63	H03	0.46	0.64	71 H		
6	66	H03	0.44	0.21	71 H		
6	68	H03	1.01	0.25	77 H	C	P
6	94	H04	0.84	0.62	57 H		
6	96	H03	0.59	0.48	57 H		
6	99	H05	0.44	0.26	57 H		
7	106	H05	0.44	0.21	57 H		
8	34	H02	0.31	0.34	57 H		
8	64	H04	0.26	0.22	71 H		
8	71	H02	0.59	0.24	71 H		

8	89 H05	0.33	0.32	57 H		
8	108 H05	0.76	0.53	57 H		
9	9 H05	0.43	0.55	59 C		
9	42 H03	0.67	0.01	18 C		
9	51 H03	0.45	0.01	18 C		
9	71 H03	0.51	0.14	59 C		
10	49 H03	0.42	0.01	17 C		
10	107 H04	0.46	0.47	23 C		
11	33 H02	0.54	0.78	20 C		
11	33 H03	0.57	0.54	20 C		
11	38 H04	0.69	0.01	18 C		
11	47 H03	1.26	0.01	18 C	C	P
11	47 H04	0.75	0.35	18 C		P
11	52 H03	1.96	0.01	18 C	C	P
11	71 H03	0.49	0.29	59 C		
11	99 H02	0.71	0.01	21 C		
13	67 H03	0.56	0.65	59 C		
13	91 H02	0.68	0.45	21 C		
16	39 H02	0.22	0.24	17 C		
17	94 H04	0.31	0.28	25 C		
22	73 H04	0.18	0.3	32 C		
22	78 H04	0.18	0.35	32 C		
23	99 H03	0.24	0.21	25 C		
30	41 H03	1.15	0.01	79 H	C	P
32	63 H02	1.01	1.11	57 H	NC	
34	24 H02	0.39	0.48	49 C		
34	99 H02	0.44	0.51	26 C		
41	94 H03	0.22	0.14	25 C		

SG 2

Row	Col	Supt	EOC-4 Volts	EOC-5 Volts	EOC-4 Cal	Tested?	Plugged?
3	21	H03	0.27	0.28	61 H		
3	60	H03	0.32	0.29	65 H		
3	63	H03	0.61	0.68	65 H		
3	74	H03	0.57	0.5	65 H		
4	36	H07	0.46	0.01	65 H		
5	42	H03	0.79	0.01	58 H		
5	45	H03	0.98	0.42	58 H		
5	114	H02	1.17	0.01	26 H	NC	
6	35	H04	0.62	0.36	65 H		
6	38	H03	0.4	0.01	65 H		
6	45	H02	0.3	0.18	59 H		
6	112	H01	1.43	0.01	26 H	NC	
6	112	H02	1.28	0.01	26 H	NC	
6	114	H02	1.35	0.01	26 H	NC	
7	4	H02	0.65	0.27	65 H		
7	12	H03	0.33	0.01	60 H		
7	12	H04	0.41	0.41	60 H		
7	44	H03	0.69	0.01	58 H		
7	77	H08	0.32	0.01	8 C		
8	112	H02	1.32	0.01	26 H	NC	
9	41	H04	0.3	0.01	15 C		
9	68	H05	0.7	0.35	66 C		
11	42	H02	0.59	0.01	15 C		
11	65	H02	0.51	0.4	66 C		
15	56	H03	0.73	0.01	15 C		
18	110	H03	0.72	0.26	22 C		
44	79	H03	0.32	0.01	36 C		
45	81	H02	0.59	0.48	37 C		

SG 3

Row	Col	Supt	EOC-4 Volts	EOC-3 Volts	Cal		Tested?	Plugged?
4	23	H02	0.73	0.5	58	H		
4	26	H02	0.41	0.33	58	H		
4	50	H03	0.73	0.01	60	H		
5	18	H03	0.48	0.45	57	H		
5	25	H04	0.57	0.01	57	H		
5	69	H03	0.85	0.22	69	H		
5	106	H08	0.23	0.01	5	C		
6	31	H08	0.21	0.01	11	C		
6	43	H02	0.95	0.64	60	H		
6	48	H02	0.66	0.79	60	H		
6	48	H05	0.82	0.77	60	H		
6	61	H05	0.46	0.32	70	H		
8	3	H02	0.69	0.68	70	H		
8	10	H05	0.49	0.47	70	H		
9	22	H02	0.45	0.36	20	C		
9	46	H04	0.54	0.45	14	C		
9	53	H04	0.46	0.3	16	C		
9	112	H05	0.39	0.01	15	C		
10	15	H05	0.44	0.39	19	C		
10	76	H03	0.24	0.19	17	C		
10	82	H04	0.56	0.32	17	C		
10	88	H05	0.46	0.36	17	C		
11	62	H02	0.37	0.38	53	C		
11	99	H03	1.07	0.24	33	C	C	P
12	36	H05	0.38	0.36	19	C		
12	37	H02	0.67	0.4	19	C		
12	88	H03	0.56	0.33	17	C		
13	75	H02	0.19	0.01	18	C		
15	75	H03	0.44	0.46	18	C		
17	29	H02	0.2	0.01	42	C		
40	91	H05	0.25	0.01	32	C		

SG 4

Row	Col	Supt	EOC-4 Volts	EOC-3 Volts	Cal	Tested?	Plugged?
1	14	H04	0.66	0.57	46 H		
1	26	H03	0.58	0.64	46 H		
1	29	H03	0.53	0.58	46 H		
2	43	H03	0.4	0.36	43 H		
3	25	H03	0.48	0.48	46 H		
3	29	H03	0.46	0.46	46 H		
3	34	H03	0.46	0.4	46 H		
3	41	H03	0.71	0.67	44 H		
4	13	H03	0.48	0.47	45 H		
4	33	H03	1.11	0.86	45 H	NC	
4	39	H03	0.69	0.66	45 H		
4	60	H06	0.4	0.36	71 H		
4	95	H02	1.17	0.37	48 H	C	P
5	38	H03	0.49	0.56	46 H		
5	42	H03	0.47	0.4	44 H		
5	62	H02	0.5	0.67	72 H		
5	62	H05	0.69	0.65	72 H		
5	75	H04	0.88	0.72	48 H		
5	98	H02	0.71	0.46	47 H		
5	107	H05	0.33	0.74	41 H		
6	27	H03	1.17	1.01	45 H	NC	
6	29	H03	0.42	0.54	45 H		
6	40	H03	0.52	0.27	43 H		
6	100	H03	0.56	0.3	48 H		
7	5	H04	0.32	0.22	72 H		
7	66	H04	0.88	0.75	79 C		P
7	75	H03	0.22	0.72	48 H		
7	97	H02	1.12	0.72	47 H	NC	
8	34	H03	0.47	1.1	45 H		
8	37	H03	1.33	0.8	45 H	NC	
8	62	H02	1.16	0.9	79 C	NC	
8	62	H03	0.98	0.91	79 C		
9	60	H05	0.29	0.34	61 C		
9	65	H02	0.67	0.7	64 C		
10	47	H03	0.96	0.81	21 C		
12	5	H04	0.45	0.24	67 C		
13	77	H05	0.25	0.27	28 C		
14	32	H03	0.48	0.48	33 C		
48	39	C06	0.41	0.74	64 H		

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1

OPERATIONAL ASSESSMENT: METHODOLOGY FOR
OUTSIDE DIAMETER STRESS CORROSION CRACKING
TOP OF TUBESHEET CIRCUMFERENTIAL INDICATIONS

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
CIRCUMFERENTIAL INDICATIONS METHODOLOGY

Operational Assessment Methodology for ODSCC Top of Tubesheet Circumferential Indications

The Watts Bar Nuclear Plant Cycle 5 operational assessment for circumferential ODSCC at the hot leg top of tubesheet expansion transitions is performed using a methodology consistent with Table 9-1 of the Electric Power Research Institute (EPRI) Report TR-107621-R1, *Steam Generator Integrity Assessment Guideline* (March 2000), for the Arithmatic method. Percent degraded area (PDA), controls burst capability of circumferential flaws. Circumferential ODSCC growth in terms of PDA was performed using the Unit 1 Cycle 4 (U1C4) data and a history review of the Unit 1 Cycle 3 (U1C3) data. A beginning of cycle maximum postulated flaw PDA was developed from the distribution of U1C4 flaws that were determined to be no detectable defect (NDD) from the post outage history review.

Structural Limit PDA Determination

The PDA associated with burst at three times normal operating pressure differential is determined using the methodology of EPRI Report TR-107197, *Depth Based Structural Analysis Methods for SG Circumferential Indications* (December 1997). A conservative normal operating pressure differential of 1300 pounds per square inch (psi) was used. Equation 6.11 of EPRI TR-107197 is used to determine the normalized burst pressure. The lower tolerance limit flow stress for ¾-inch outside diameter (OD) x 0.043-inch nominal wall thickness tubing was used. The normalized burst pressure is found to be 0.245. At a normalized burst pressure of 0.245, the structural limit PDA is then obtained from Figure 6-18 of EPRI TR-107197, using the lower 95 percent (%) prediction interval line for P_n. The structural limit PDA is 77.5%, however, a value of 77% will be used for this evaluation.

U1C4 Circumferential ODSCC PDA Distribution

To determine the distribution of PDAs for U1C4, a methodology was utilized that already existed as part of a prior performance demonstration for circumferential ODSCC sizing in hardroll expanded tubes. The U1C4 PDA distribution was obtained by multiplying the reported flaw arc length times the reported maximum depth to obtain a bounding PDA. This PDA was then adjusted by the ratio of PDA to maximum depth for the hardroll circumferential ODSCC pulled tube database. The validity of this process is shown in Figure 1. Figure 1 presents a plot of the pulled tube database flaws using arc length from destructive examination times maximum depth from destructive examination times the ratio of PDA to maximum depth determined for the pulled tubes. As seen from this figure, the adjusted values less than one volt (< 1V) track closely to a 1:1 line. All flaws identified in the U1C4 inspection were < 1V. The adjustment value of 0.60 represents the average PDA to maximum depth ratio for the pulled tubes.

Arc length determination was based on an updated methodology developed by Westinghouse that greatly improves the arc length measurement accuracy. Maximum depth determination was also based on this updated methodology, which greatly improves maximum depth measurement accuracy. To gauge the effectiveness of this method against the pulled tubes, the arc length measurement (by nondestructive examination [NDE]) and maximum depth measurement (by NDE) of the pulled tubes was multiplied by the PDA to maximum depth adjustment. The results of the calculated PDA versus PDA from destructive examination are shown in Figure 2. Uncertainties based on PDA prediction compared to truth were developed and applied at the PDA evaluation level.

Cycle 4 PDA Growth Evaluation

The methodology described above was used to define PDA values for the U1C4 flaws and the U1C3 flaws that could be observed in a history (look back) review. The flaw PDA values were calculated using the arc length from NDE times the maximum depth from NDE, adjusted by the ratio of PDA to maximum depth for the pulled tubes. As more than half of the U1C4 circumferential ODSCC indications were reported in Steam Generator 4, the growth evaluation was concentrated in this steam generator. The largest flaw amplitudes were also reported in Steam Generator 4. The postulated flaw left in service was defined by the 95% cumulative PDA reported for U1C4 flaws that were determined to be NDD in history.

Operational Assessment Evaluation Based on PDA Determined from Arc Length, Maximum Depth (MD), and PDA/MD Ratio

Using the upper bound 90% probability, 50% confidence value for an NDE determined PDA of 24.7%, which represents the upper 95% cumulative probability PDA from U1C4 that was determined to be NDD in U1C3, the uncertainty adjusted value could represent a PDA as large as 53.13%. The 95% cumulative growth of 17% is added to this value to obtain a maximum end-of-cycle (EOC)-5 PDA of 70.13%, which is less than the structural limit of 77%, thus the performance criterion is satisfied. At a predicted EOC-5 PDA of 70.13%, the predicted burst pressure using the lower 95% prediction interval curve of Figure 6-18 of EPRI TR-107197 is 4926 psi. The same PDA/MD ratio was applied to the U1C4 and U1C3 flaws. In this case, the PDA/MD ratio is independent of the resultant solution.

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT (WBN) UNIT 1
OUTSIDE DIAMETER STRESS CORROSION CRACKING (ODSCC)
CIRCUMFERENTIAL INDICATIONS METHODOLOGY

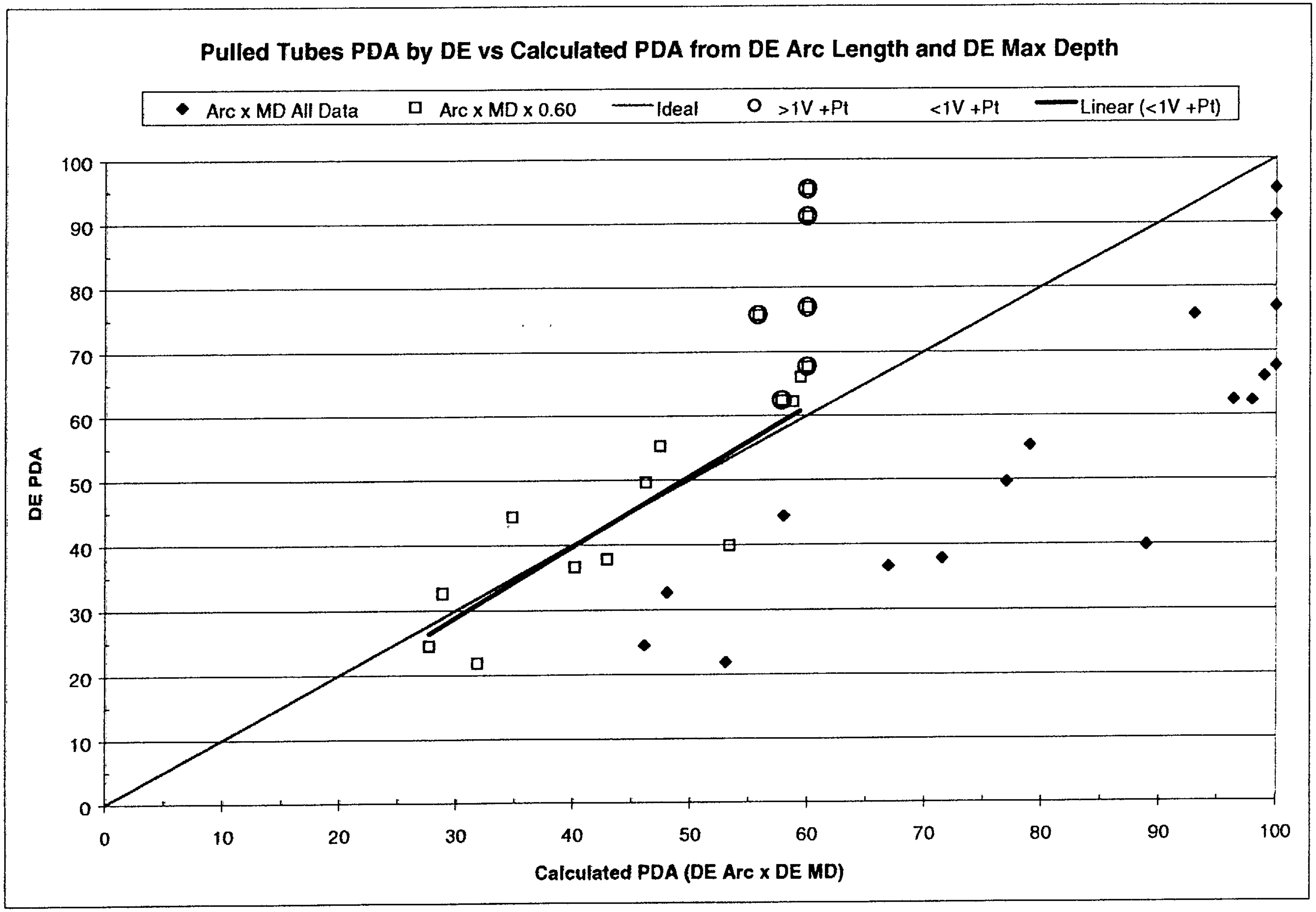
Alternate OA Evaluation Based on Flaw Amplitude

The 95% cumulative probability plus point (+Pt) voltage for flaws NDD in history is 0.28 volts. A 10% voltage measurement uncertainty is included, resulting in an uncertainty adjusted NDD voltage of 0.31 volts. The 95% cumulative probability voltage growth is 0.19 volts. Therefore, the voltage that could be expected at U1C5 is approximately 0.50 volts, or approximately equal to the maximum observed U1C4 voltage of 0.54 volts. The available data for pulled tubes with circumferential ODSCC in hardroll expansions is approximately 20 tubes. Figure 3 presents a plot of the pulled tube maximum +Pt amplitude vs both PDA and burst pressure. As seen from this figure, a 0.50 volt maximum +Pt amplitude has a nominal PDA of approximately 46%, and burst pressure of approximately 6400 psi at operating temperatures. The R value for the volts versus PDA curve of Figure 3 is 0.69. At the 90/50 lower bound, for a maximum +Pt amplitude of 0.50 volts, the predicted PDA is 62%, and predicted burst pressure is approximately 5400 psi (which matches well with the predicted burst pressure based on arc length times maximum depth of 4926 psi). Based on the 90/50 lower bound volts versus burst pressure curve of Figure 3, the $3\Delta P$ value of 3900 psi is represented by maximum +Pt amplitude of 1.6 volts.

Conclusion

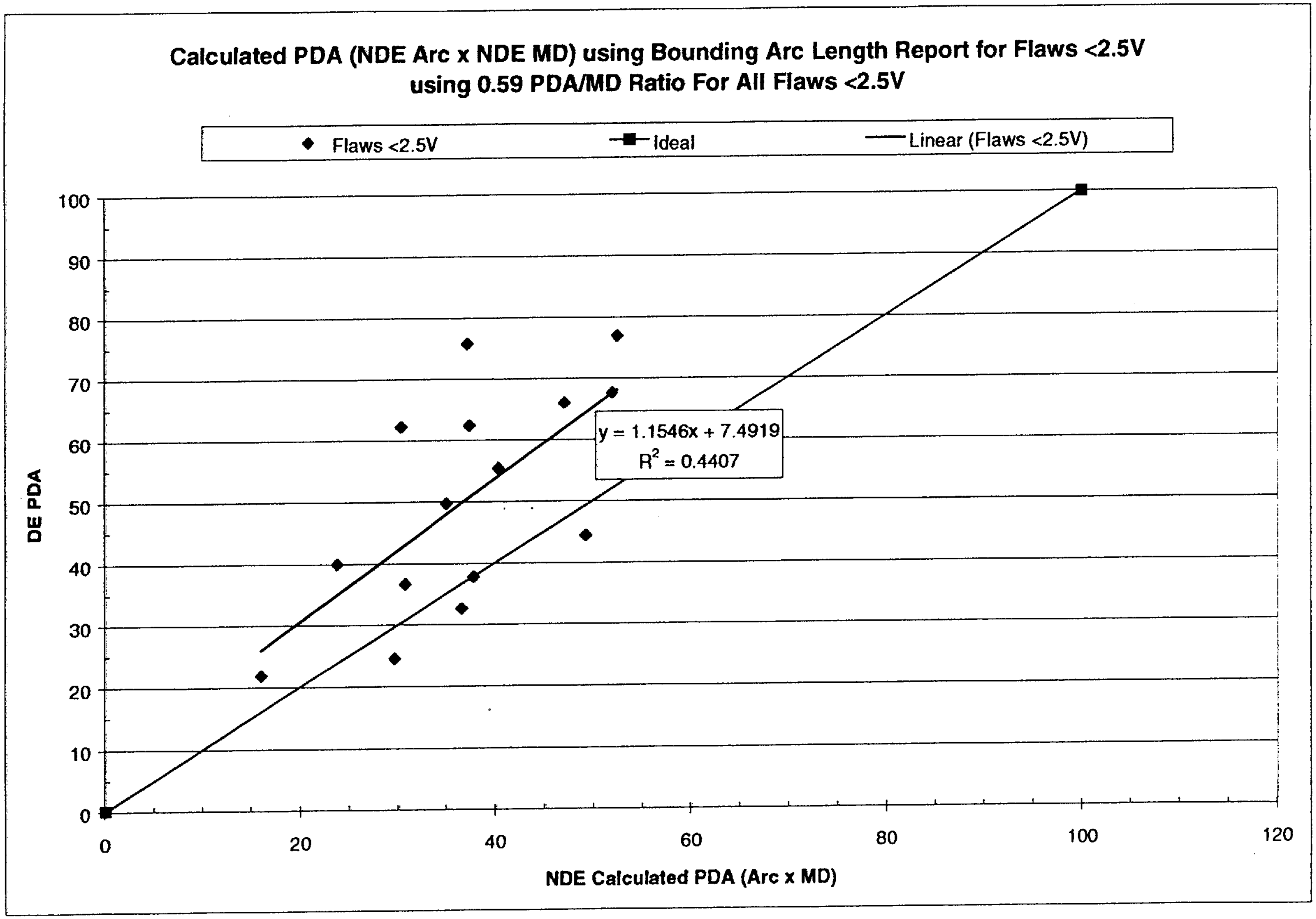
A simplistic calculation of EOC-5 PDA using the methodology of Table 9-1 of the EPRI Report TR-107621-R1 Steam Generator Integrity Assessment Guidelines has shown that the predicted PDA is less than the structural limit PDA, thus the performance criterion is met. An empirical relation between +Pt maximum flaw voltage and PDA and burst pressure from destructive examination for pulled tubes produces EOC-5 PDA and burst capabilities that are quite close to the predicted values based on flaw arc length and maximum depth, and help to serve as an independent verification of the prediction methodology.

Figure 1



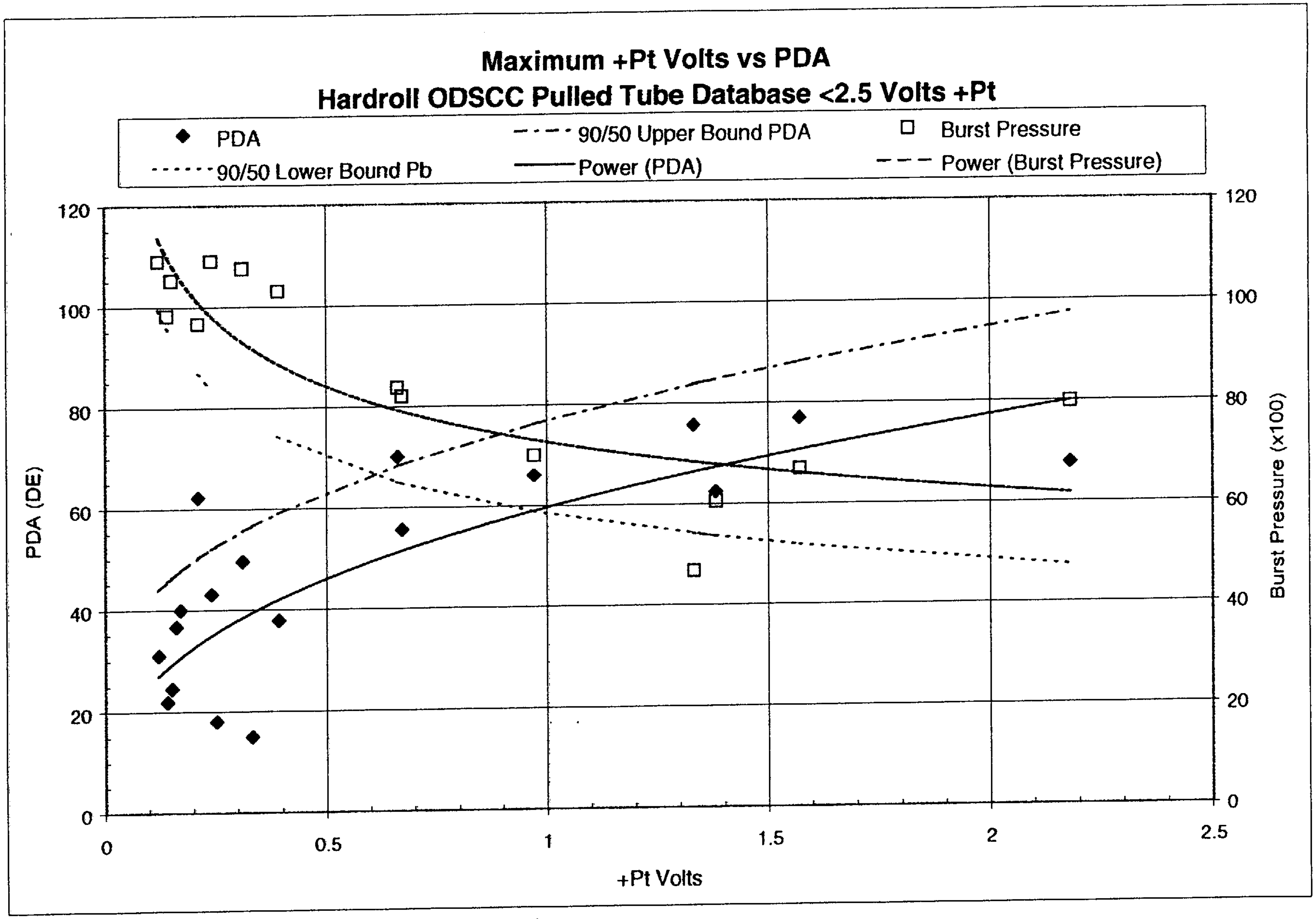
Pulled Tubes PDA by DE vs Calculated PDA from DE Arc Length and DE Max Depth
Arc x MD All Data
Arc x MD x 0.60
Ideal
>1V +Pt
<1V +Pt
Linear (<1V +Pt)
DE PDA
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Calculated PDA (DE Arc x DE MD)

Figure 2



Calculated PDA (NDE Arc x NDE MD) using Bounding Arc Length Report for Flaws <2.5V
using 0.59 PDA/MD Ratio For All Flaws <2.5V
Flaws <2.5V
Ideal
Linear (Flaws <2.5V)
y = 1.1546x + 7.4919
R2 = 0.4407
DE PDA
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
NDE Calculated PDA (Arc x MD)

Figure 3



Maximum +Pt Volts vs PDA
Hardroll ODSCC Pulled Tube Database <2.5 Volts +Pt
PDA
90/50 Upper Bound PDA
Burst Pressure
90/50 Lower Bound Pb
Power (PDA)
Power (Burst Pressure)
PDA (DE)
Burst Pressure (x100)
+Pt Volts
0
20
40
60
80
100
120
0.5
1
1.5
2
2.5