SG-95-12-010

D. C. COOK UNIT 1

1995 INTERIM PLUGGING CRITERIA 90 DAY REPORT

DECEMBER 1995

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GLOSSARY

APC	Alternate Plugging Criteria
BOC	Beginning of Cycle
CPDF	Cumulative Probability Distribution Function
EFPD	Effective Full Power Day
EFPY	Effective Full Power Year
ECT	Eddy Current Test
EOC	End of Cycle
GPM	Gallons per Minute
INR	Indication Not Reportable
IPC	Interim Plugging Criteria
NDE	Non Destructive Examination
NRC	Nuclear Regulatory Commision
ODSCC	Outside Diameter Stress Corrosion Cracking
PI	Potential Indication
POD	Probability of Detection
PWSCC	Primary Water Stress Corrosion Cracking
RTS	Return to Service
SG	Steam Generator
SER	Safety Evaluation Report
RPC	Rotating Pancake Coil
SLB	Steam Line Break
TSP	Tube Support Plate

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1.0 INTRODUCTION

This report provides the D.C. Cook Unit 1 steam generator tube support plate (TSP) bobbin voltage distribution summary, together with postulated Steam Line Break (SLB) leak rate and tube burst probability analysis results, in support of the implementation of a 2.0 volt Interim Plugging Criteria (IPC) for Cycle 15 as outlined in the NRC Draft Generic Letter, Reference 8.1. Calculations of leak rates and probability of tube burst are reported, based on actual End Of Cycle 14 (EOC-14) bobbin voltage distributions. Also provided are projections of bobbin voltage distributions, leak rates and burst probabilities for Cycle 15 operation. The methodology used in these evaluations is in accordance with the previously published Westinghouse technical report, Reference 8.2.

The application of the TSP Interim Plugging Criteria at D.C. Cook Unit 1 involves bobbin coil inspection of the tube bundle and plugging of > 2.0 volt TSP indications which are confirmed by Rotating Pancake Coil (RPC) inspection results. Plugging of > 5.6 volts TSP bobbin indications is required regardless of RPC inspection results. Calculational results of predicted SG tube leak rate and probability of burst during a postulated SLB at EOC-15 are well below regulatory requirements as outlined in the NRC SER, Reference 8.3.

2.0 SUMMARY AND CONCLUSIONS

SLB leak rate and tube burst probability analyses were performed for the actual EOC-14 bobbin voltage distributions and for projected for EOC-15 distributions at D.C. Cook Unit 1. SG 11 was found to be the limiting SG at EOC-14, with the highest number of indications, bobbin voltage amplitude and leak rate for the postulated SLB. The tube burst probability at EOC-14 is low (1.9 E-05), with only one tube burst occurring (in SG 12) in separate calculations of 250,000 Monte Carlo simulations for each SG. SG 11 is predicted to be limiting at EOC-15, with the highest number of indications, bobbin voltage amplitude and leak rate for the postulated SLB. The tube burst probability at EOC-15 is low, varying between 1.9 E-05 and 3.1 E-05 between the four SGs. SLB leak rates for the actual EOC-14 and projected EOC-15 distributions are 0.23 and 0.70 gpm, respectively. These calculations demonstrate that IPC application at EOC-14 (actual distribution) and at EOC-15 (predicted for POD = 0.6) will satisfy NRC criteria for allowable leakage and burst probability.

A total of 597 bobbin indications (in the tubes in service during Cycle 14) were reported during the EOC-14 inspection. The highest bobbin voltage recorded during this inspection was 1.71 volts, so there are no indications above the 2.0 volt IPC repair limit and no tube had to be plugged because of ODSCC at TSP intersections. Five of the 597 were RPC inspected, of which 3 were confirmed. Thirteen indications were removed from service, but none because of ODSCC TSP indications. Accordingly, 584 of the 597 indications were returned to service for Cycle 15.

Sixty one of the 597 bobbin indications were > 1.0 volt and all were < 1.8 volts; four of the 61 were RPC inspected; two of these four were confirmed; one of these four was plugged for reasons other than ODSCC at TSPs.

SG 11 was limiting at EOC-14 with 199 indications (in the tubes in service during Cycle 14), of which 2 were RPC inspected, with 1 confirmation. Twenty of the 199 indications were reported as > 1.0 volt and $\leq$ 1.71 volts (the highest reported bobbin voltage during the outage). Two of the 199 indications were removed from service, for reasons other than ODSCC at TSP.

For the actual EOC-14 bobbin voltage distribution, the limiting SLB tube leak rate is calculated to be 0.23 gpm and the limiting tube burst probability is < 4.0 E-06 E-06 for SG 11 (1.9 E-05 for SG 12), substantially lower than the D.C. Cook Unit 1 allowable SLB tube leakage limit and the NRC reporting guideline for the tube burst probability (Reference 8.3). These results of actual EOC-14 tube leak rate and burst probability are lower than the corresponding predictions (0.44 gpm and 1.9 E-05) performed at BOC-14, demonstrating the conservatism of the prediction methodology.

During the outage, tubes previously plugged in accordance with prior repair criteria for ODSCC at TSPs were deplugged, inspected and either returned to service in accordance with IPC criteria or replugged. Accordingly, 39 such indications (23 with > 1.0 V and < 1.7 V bobbin amplitude) were returned to service, for a total of 623 indications returned to service for Cycle 15 operation in accordance with IPC criteria. (During this outage, an extensive parallel effort was conducted to reroll and return to service tubes previously plugged for PWSCC.)

Using the NRC criteria of POD = 0.6 to calculate the performance of the limiting SG during the next D.C. Cook Unit 1 operating cycle, the SLB tube leak rate is projected to be 0.70 gpm for SG 11 and the tube burst probability is projected to be 2.9 E-05 for SG 13 at EOC-15. These results are much lower than the D.C. Cook Unit 1 IPC requirement for allowable tube leakage and the NRC guideline for tube burst probability; accordingly Cycle 15 operation of D.C. Cook Unit 1 is considered to be in compliance with requirements of the NRC SER of Reference 8.3.

3.0 EOC-14 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 EOC-14 INSPECTION RESULTS

In accordance with the IPC guidance provided by the NRC draft generic letter (Reference 8.1), the end of Cycle 14 (EOC-14) inspection of the D.C. Cook Unit 1 steam generators (SG) consisted of a complete 100% bobbin probe full length examination of all TSP intersections in the tube bundles of all four SGs. RPC examination was performed for all bobbin indications with amplitudes > 1.5 V. The NRC IPC criteria require that RPC confirmed indications of > 2.0 V bobbin amplitude shall be plugged and that > 5.6 V bobbin amplitude shall be plugged. Since the highest bobbin indication reported during this inspection was 1.71 V, independent of RPC confirmation, none of the tubes that were in service during Cycle 14 required plugging for ODSCC at TSP intersections. During this outage, tubes previously plugged in accordance with prior repair criteria for ODSCC at TSPs were deplugged, inspected and either returned to service in accordance with IPC criteria or replugged.

A summary of ECT indication distributions for all steam generators is shown on Table 3-1. For those tubes that were in service for Cycle 14, Table 3-1 provides the number of field bobbin indications, the number of these field bobbin indications that were RPC inspected, the number of RPC confirmed indications, the number of indications in plugged tubes, the number of Cycle 14 in-service indications that remain active for Cycle 15, the indications recovered from deplugged tubes which were returned to service for Cycle 15, and the subsequent total indication population being returned to service (RTS) for Cycle 15 (BOC-15). Overall, the combined data for the D.C. Cook Unit 1 steam generators shows that:

- Out of a total of 597 indications which were in-service during Cycle 14 and were identified during the EOC-14 inspection, 13 were removed from service (for causes other than ODSCC at TSP intersections), leaving 584 which were returned to service for Cycle 15. All RPC confirmed indications have bobbin amplitudes of $\leq$ 1.8 volt.

- Of the 597 indications, a total of 5 were RPC inspected. Three of the five were > 1.5 V but $\leq$ 1.8 V.

- Of the 5 RPC inspected, a total of 3 were RPC confirmed.

- Additionally, 39 indications from deplugged tubes were recovered and returned to service, for a total of 623 indications returned to service for Cycle 15 operation in accordance with IPC criteria.

Review of Table 3-1 indicates that steam generator 11 has more total as well as higher amplitude BOC-15 indications (a quantity of 211, with 26 indications > 1.0 volt) than any of the other three SGs, thereby it potentially will be the limiting SG at EOC-15.

Figure 3-1 shows the actual bobbin voltage distribution for tubes that were in service during Cycle 14, as determined from the EOC-14 ECT inspection; note that SG 11 appears to predominate over the other three SGs. The largest bobbin indication found in the EOC-14 inspection was 1.71 volts in SG 11 (shown in the 1.8 volt bin). Figure 3-2 shows the distribution of the relatively small population of those EOC-14 indications which were plugged and taken out of service (for reasons other than IPC) and Figure 3-3 shows the bobbin voltage distribution of indications in service during Cycle 14 returned to service for BOC-15.

During the outage, tubes previously plugged in accordance with prior repair criteria for ODSCC at TSPs were deplugged, inspected and either returned to service in accordance with IPC criteria or replugged; a summary of these tubes is presented on Table 3-2. Accordingly, 39 such indications (23 with >1.0 V and $\leq$ 1.7 V bobbin amplitude) in the four SGs were returned to service for Cycle 15 in accordance with IPC criteria. Figure 3-4 shows the bobbin voltage distribution for the deplugged indications which were returned to service for Cycle 15. Figure 3-5 shows the total indications (those continuing from Cycle 14 service and those deplugged at EOC-14) which were returned to service for Cycle 15.

The distribution of EOC-14 indications as a function of support plate elevation, summarized in Table 3-3 and shown on Figure 3-6, shows the predisposition of ODSCC to occur in the first few hot leg TSPs (515 of 597 indications occurred in the first two hot leg TSPs), although the mechanism does extend to higher TSPs. There were no bobbin indications reported in the cold leg. This distribution indicates the predominant temperature dependence of ODSCC at D.C. Cook Unit 1, similar to that observed at other plants.

3.2 VOLTAGE GROWTH RATES

Average bobbin voltage growth rates for the D.C. Cook Unit 1 steam generators, shown on Table 3-4, provide a comparison of recent operating cycles. These results provide an interesting overview of the progress of IPC over the last five years. The increase in the number of indications with V < 0.75 (where the number of indications increases from 30 to 356 to 445 during Cycles 12, 13 and 14, respectively) is attributed to improved ECT practice. Over the 1990 - 1995 time period, the focus on

ECT, including equipment, standards and analyst guidelines and training, has resulted in more accuracy and discrimination of bobbin probe signals, so that more low voltage indications are being reported. The preponderance of PIs are at low voltage, with the attendant lower accuracy in voltage growth associated with differences between small absolute numbers. The trend in growth rates is not definitive, since all average growth rates are too small for meaningful trend analysis.

The average growth rate comparisons for each SG during Cycle 14 are summarized on Table 3-5. The average growth rates varied between 3.0% and 9.9%, between SGs, with an overall average of 5.1% per EFPY. The average growth for indications with a BOC bobbin voltage > 0.75 volt is 5.0% per EFPY and for indications < 0.75 volt is 5.8% per EFPY. SG 12 has the highest average voltage at BOC-14 whereas SG 11 has the largest average growth during Cycle 14.

Another cycle growth comparison is provided in more detail by the Cumulative Probability Distribution Functions (CPDF) for Cycle 12, 13 and 14 data summarized on Tables 3-6, 3-7, and 3-8, respectively, and shown on Figure 3-7. There is a modest difference between Cycle 13 and 14 and the order of increasing cycle growth for the CPDF shown on Figure 3-7 agrees with the average ranking from Table 3-4. The NRC generic letter recommends that the more conservative growth distribution from the last two cycles be used for projecting EOC distributions. Accordingly, the Cycle 14 bobbin voltage growth rates will be used for prediction of EOC-15 conditions; these rates are developed from the 1995 EOC-14 inspection data and a reevaluation of the same indications from the previous (1994) inspection ECT signals.

Table 3-8 shows the Cumulative Probability Distribution Function (CPDF) for each SG during Cycle 14; the same data is presented in graphical form on Figure 3-8. For conservatism, a worst case hybrid growth distribution is defined on Table 3-8, which envelopes the actual EOC-14 distribution with the simultaneous limitations of SG 11 (highest average growth and number of indications) and of SG 12 (highest voltage increment of 0.7 volt). This hybrid growth is imposed on all four SGs, to provide a conservative basis for predicting EOC-15 conditions.

The EOC-14 field bobbin data summarized on Table 3-1 (the basis for EOC-15 bobbin voltage and all tube leakage and burst probability calculations reported herein) does not include INR (Indication Not Reportable) field calls. Generally, growth estimates are calculated only for the cases where bobbin signal voltage is available for both inspections; i.e., no assumption about the signal voltage for prior year is made if a reliable flaw indication is not available. However, new indications which were called INRs in the EOC-13 inspection were included in the growth analysis (and the bobbin voltage reported at EOC-13 was used) as it results in slightly more conservative growth rates.

3.3 NDE UNCERTAINTIES

The NDE uncertainties applied for the Cycle 15 voltage projections in this report are documented in References 8.2 and 8.4. The probe wear uncertainty has a standard deviation of 7.0% 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 included in the Monte Carlo analyses used to predict the EOC-15 voltage distributions.

Table 3 - 1
D. C. Cook Unit 1 1995 EOC-14
Summary of Inspection and Repair For Tubes in Service During Cycle 14

Voltage Bin	Steam Generator 11							Steam Generator 12						
	In-Service During Cycle 14					EOC-14 Deplugged Tubes Returned to Service	BOC-15 All All Tubes Returned to Service	In-Service During Cycle 14					EOC-14 Deplugged Tubes Returned to Service	BOC-15 All Tubes Returned to Service
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service			Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service		
0.2	2	0	0	0	2	0	2	3	1	1	0	3	0	3
0.3	5	0	0	0	5	0	5	8	0	0	0	8	0	8
0.4	20	0	0	1	19	1	20	14	0	0	0	14	0	14
0.5	41	0	0	0	41	1	42	12	0	0	0	12	0	12
0.6	28	0	0	0	28	0	28	17	0	0	3	14	0	14
0.7	28	0	0	1	27	0	27	16	0	0	0	16	0	16
0.8	24	0	0	0	24	2	26	16	0	0	1	15	0	15
0.9	15	0	0	0	15	2	17	7	0	0	0	7	0	7
1	16	0	0	0	16	2	18	12	0	0	0	12	3	15
1.1	9	1	0	0	9	1	10	6	0	0	0	6	1	7
1.2	4	0	0	0	4	3	7	1	0	0	0	1	2	3
1.3	3	0	0	0	3	0	3	2	0	0	0	2	0	2
1.4	2	0	0	0	2	0	2	4	0	0	1	3	1	4
1.5	1	0	0	0	1	1	2	1	0	0	0	1	6	7
1.6	0	0	0	0	0	0	0	1	1	1	0	1	0	1
1.7	0	0	0	0	0	1	1	1	1	0	0	1	0	1
1.8	1	1	1	0	1	0	1	0	0	0	0	0	0	0
Total	199	2	1	2	197	14	211	121	3	2	5	116	13	129
> 1V	20	2	1	0	20	6	26	16	2	1	1	15	10	25

Voltage Bin	Steam Generator 13							Steam Generator 14						
	In-Service During Cycle 14					EOC-14 Deplugged Tubes Returned to Service	BOC-15 All All Tubes Returned to Service	In-Service During Cycle 14					EOC-14 Deplugged Tubes Returned to Service	BOC-15 All Tubes Returned to Service
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service			Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service		
0.2	1	0	0	0	1	0	1	1	0	0	0	1	0	1
0.3	4	0	0	0	4	0	4	13	0	0	0	13	0	13
0.4	10	0	0	0	10	0	10	23	0	0	0	23	0	23
0.5	16	0	0	0	16	0	16	23	0	0	0	23	0	23
0.6	16	0	0	0	16	0	16	31	0	0	2	29	1	30
0.7	14	0	0	0	14	0	14	31	0	0	1	30	1	31
0.8	11	0	0	0	11	0	11	22	0	0	1	21	0	21
0.9	3	0	0	0	3	0	3	11	0	0	1	10	0	10
1	7	0	0	0	7	1	8	15	0	0	1	14	2	16
1.1	1	0	0	0	1	0	1	6	0	0	0	6	2	8
1.2	5	0	0	0	5	2	7	5	0	0	0	5	0	5
1.3	1	0	0	0	1	0	1	2	0	0	0	2	1	3
1.4	1	0	0	0	1	1	2	3	0	0	0	3	0	3
1.5	0	0	0	0	0	0	0	1	0	0	0	1	1	2
1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	90	0	0	0	90	4	94	187	0	0	6	181	8	189
> 1V	8	0	0	0	8	3	11	17	0	0	0	17	4	21

Table 3 - 2
D. C. Cook Unit 1 1995 EOC-14
Summary of Inspection and Repair For Tubes Deplugged at EOC-14

Voltage Bin	Steam Generator 11					Steam Generator 12				
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.4	1	0	0	0	1	0	0	0	0	0
0.5	1	0	0	0	1	0	0	0	0	0
0.6	0	0	0	0	0	0	0	0	0	0
0.7	0	0	0	0	0	0	0	0	0	0
0.8	2	0	0	0	2	0	0	0	0	0
0.9	2	0	0	0	2	0	0	0	0	0
1	2	0	0	0	2	3	0	0	0	3
1.1	1	0	0	0	1	1	0	0	0	1
1.2	3	0	0	0	3	4	0	0	2	2
1.3	0	0	0	0	0	1	0	0	1	0
1.4	0	0	0	0	0	1	0	0	0	1
1.5	1	0	0	0	1	7	0	0	1	6
1.7	1	1	1	0	1	0	0	0	0	0
1.8	1	1	1	1	0	1	1	1	1	0
1.9	0	0	0	0	0	1	1	1	1	0
2.3	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	1	1	1	1	0
Total	15	2	2	1	14	20	3	3	7	13
> 1V	7	2	2	1	6	17	3	3	7	10
> 2V	0	0	0	0	0	1	1	1	1	0

Voltage Bin	Steam Generator 13					Steam Generator 14				
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.4	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0	0	0	0	0	0	0
0.6	0	0	0	0	0	1	0	0	0	1
0.7	0	0	0	0	0	2	0	0	1	1
0.8	0	0	0	0	0	0	0	0	0	0
0.9	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	1	2	0	0	0	2
1.1	0	0	0	0	0	2	0	0	0	2
1.2	2	0	0	0	2	0	0	0	0	0
1.3	0	0	0	0	0	3	0	0	2	1
1.4	1	0	0	0	1	0	0	0	0	0
1.5	0	0	0	0	0	1	0	0	0	1
1.7	0	0	0	0	0	0	0	0	0	0
1.8	0	0	0	0	0	0	0	0	0	0
1.9	0	0	0	0	0	0	0	0	0	0
2.3	1	1	1	1	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0
Total	5	1	1	1	4	11	0	0	3	8
> 1V	4	1	1	1	3	6	0	0	2	4
> 2V	1	1	1	1	0	0	0	0	0	0

Table 3 -3
D. C. Cook Unit 1 1995 Outage
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 14

Tube Support Plate	Steam Generator 11				Steam Generator 12			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	133	1.71	0.68	0.065	58	1.59	0.72	0.056
2H	46	1.08	0.66	0.065	45	1.69	0.73	0.027
3H	15	1	0.59	0.064	8	0.7	0.50	0.015
4H	4	0.65	0.41	0.025	8	0.59	0.42	0.000
5H	0	-	-	-	2	0.54	0.46	-0.090
6H	1	0.36	0.36	-0.030	0	-	-	-
7H	0	-	-	-	0	-	-	-
Total	199				121			

Tube Support Plate	Steam Generator 13				Steam Generator 14			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	59	1.18	0.64	0.035	81	1.46	0.69	-0.011
2H	24	1.4	0.65	0.028	69	1.36	0.64	0.048
3H	6	0.78	0.58	0.033	29	1.13	0.55	0.028
4H	0	-	-	-	6	0.69	0.47	0.072
5H	1	0.21	0.21	0.030	1	0.36	0.36	0.110
6H	0	-	-	-	0	-	-	-
7H	0	-	-	-	1	0.36	0.36	0.100
Total	90				187			

Tube Support Plate	Composite of All Four SGs			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	331	1.71	0.68	0.039
2H	184	1.69	0.67	0.044
3H	58	1.13	0.56	0.033
4H	18	0.69	0.43	0.029
5H	4	0.54	0.37	-0.010
6H	1	0.36	0.36	-0.030
7H	1	0.36	0.36	0.100
Total	597			

Table 3 - 4
D. C. Cook Unit-1 1995 Outage
Average Voltage Growth History
Composite of All Steam Generator Data

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percentage Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
	Cycle 14 (1994 - 1995) - 390.54 EFPD					
Entire Voltage Range	597	0.62	0.034	0.031	5.4%	5.1%
V_{BOC} < .75 Volts	445	0.50	0.031	0.029	6.3%	5.8%
≥ .75 Volts	152	0.94	0.050	0.047	5.3%	5.0%
	Cycle 13 (1992 - 1994) - 444.2 EFPD					
Entire Voltage Range	514	0.66	0.010	0.008	1.2%	1.0%
V_{BOC} < .75 Volts	356	0.50	~ 0	~ 0	~ 0 %	~ 0 %
≥ .75 Volts	158	0.95	0.03	0.025	2.6%	2.1%
	Cycle 12 (1990 - 1992) - 455 EFPD					
Entire Voltage Range	201	1.00	0.020	0.016	1.6%	1.3%
V_{BOC} < .75 Volts	30	0.67	0.080	0.064	9.6%	7.7%
≥ .75 Volts	171	1.07	0.010	0.008	0.8%	0.6%

Table 3 - 5
D. C. Cook Unit -1 1995 Outage
Average Voltage Growth During Cycle 14

	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	597	0.62	0.034	0.031	5.4%	5.1%
V_{BOC} < .75 Volts	445	0.50	0.031	0.029	6.3%	5.8%
≥ .75 Volts	152	0.94	0.050	0.047	5.3%	5.0%
	Steam Generator 11					
Entire Voltage Range	199	0.60	0.064	0.059	10.6%	9.9%
V_{BOC} < .75 Volts	156	0.52	0.051	0.047	9.8%	9.2%
≥ .75 Volts	43	0.90	0.110	0.103	12.3%	11.5%
	Steam Generator 12					
Entire Voltage Range	121	0.65	0.036	0.034	5.6%	5.2%
V_{BOC} < .75 Volts	83	0.49	0.032	0.030	6.4%	6.0%
≥ .75 Volts	38	0.99	0.047	0.044	4.7%	4.4%
	Steam Generator 13					
Entire Voltage Range	90	0.60	0.033	0.031	5.5%	5.1%
V_{BOC} < .75 Volts	70	0.50	0.029	0.027	5.9%	5.5%
≥ .75 Volts	20	0.95	0.046	0.043	4.8%	4.5%
	Steam Generator 14					
Entire Voltage Range	187	0.62	0.020	0.019	3.2%	3.0%
V_{BOC} < .75 Volts	136	0.50	0.026	0.024	5.1%	4.8%
≥ .75 Volts	51	0.95	0.005	0.004	0.5%	0.4%

Based on Cycle 14 duration of 390.54 EFPD

Table 3 -6
D. C. Cook Unit 1
Signal Growth Statistics For Cycle 12 ('90 to '92) on EFPY Basis

Delta Volts	Steam Generator 11		Steam Generator 12		Steam Generator 13	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.3	0	0	0	0	0	0
-0.2	0	0	1	0.021	0	0
-0.1	5	0.086	2	0.063	1	0.037
0	23	0.483	5	0.167	5	0.222
0.1	24	0.897	27	0.729	16	0.815
0.2	6	1	7	0.875	5	1
0.3			4	0.958		
0.4			2	1		
Total	58		48		27	

Delta Volts	Steam Generator 14		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.3	2	0.031	2	0.010
-0.2	3	0.077	4	0.030
-0.1	13	0.277	21	0.136
0	22	0.615	55	0.414
0.1	19	0.908	86	0.848
0.2	4	0.969	22	0.960
0.3	1	0.985	5	0.985
0.4	1	1	3	1
Total	65		198	

Table 3 - 7
D. C. Cook Unit 1
Signal Growth Statistics For Cycle 13 ('92 to '94) on EFPY Basis

Delta Volts	Steam Generator 11		Steam Generator 12		Steam Generator 13	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.2	1	0.006	3	0.029	1	0.012
-0.1	18	0.122	5	0.078	5	0.071
0	58	0.494	35	0.417	33	0.464
0.1	59	0.872	48	0.883	35	0.881
0.2	18	0.987	8	0.961	9	0.988
0.3	2	1	3	0.990	1	1
0.4			1	1		
Total	156		103		84	

Delta Volts	Steam Generator 14		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.2	6	0.035	11	0.021
-0.1	10	0.094	38	0.095
0	71	0.509	197	0.479
0.1	70	0.918	212	0.891
0.2	14	1	49	0.986
0.3			6	0.998
0.4			1	1
Total	171		514	

Table 3 - 8
D. C. Cook Unit 1 1995
Signal Growth Statistics For Cycle 14 ('94 to '95) on an EFPY Basis

Delta Volts	Steam Generator 11		Steam Generator 12		Steam Generator 13	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.3	0	0	0	0	0	0
-0.2	0	0	2	0.017	0	0
-0.1	7	0.035	6	0.066	2	0.022
0	57	0.322	47	0.455	32	0.378
0.1	81	0.729	45	0.826	41	0.833
0.2	36	0.910	12	0.926	13	0.978
0.3	13	0.975	6	0.975	2	1
0.4	2	0.985	1	0.983		
0.5	2	0.995	1	0.992		
0.6	1	1	0	0.992		
0.7			1	1		
Total	199		121		90	

Delta Volts	Steam Generator 14		Cumulative		Hybrid #	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.3	2	0.011	2	0.003	0	0
-0.2	1	0.016	3	0.008	0	0
-0.1	8	0.059	23	0.047	7	0.035
0	64	0.401	200	0.382	57	0.320
0.1	90	0.882	257	0.812	81	0.725
0.2	19	0.984	80	0.946	36	0.905
0.3	2	0.995	23	0.985	13	0.970
0.4	0	0.995	3	0.990	2	0.980
0.5	1	1	4	0.997	2	0.990
0.6			1	0.998	1	0.995
0.7			1	1	1	1
Total	187		597		200	

Growth distribution for SG-11 plus the largest growth observed, which is in SG-12.

Figure 3 -1
D. C. Cook Unit -1 1995 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 14

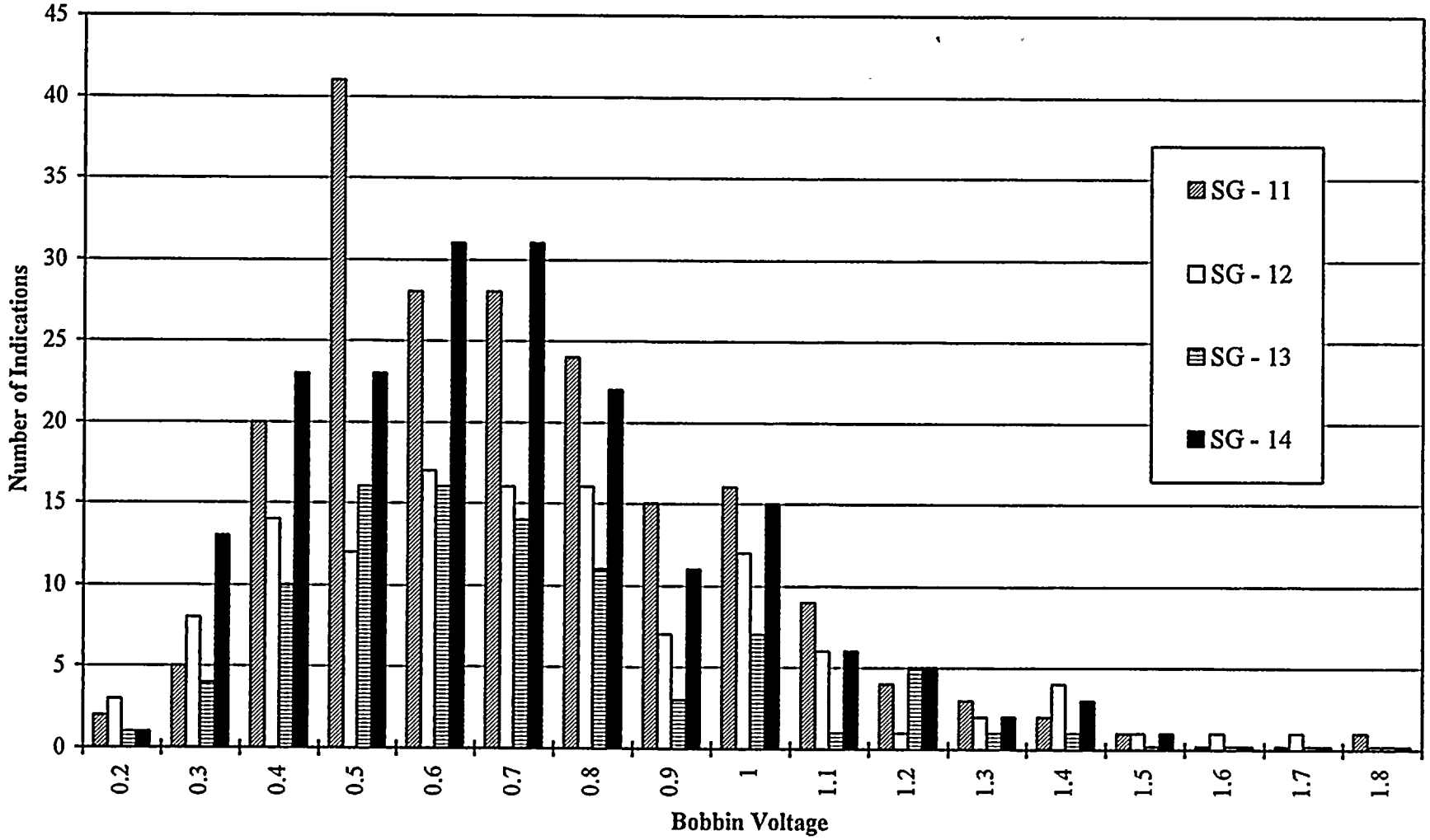


Figure 3 -2
D. C. Cook Unit -1 1995 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 14 Service

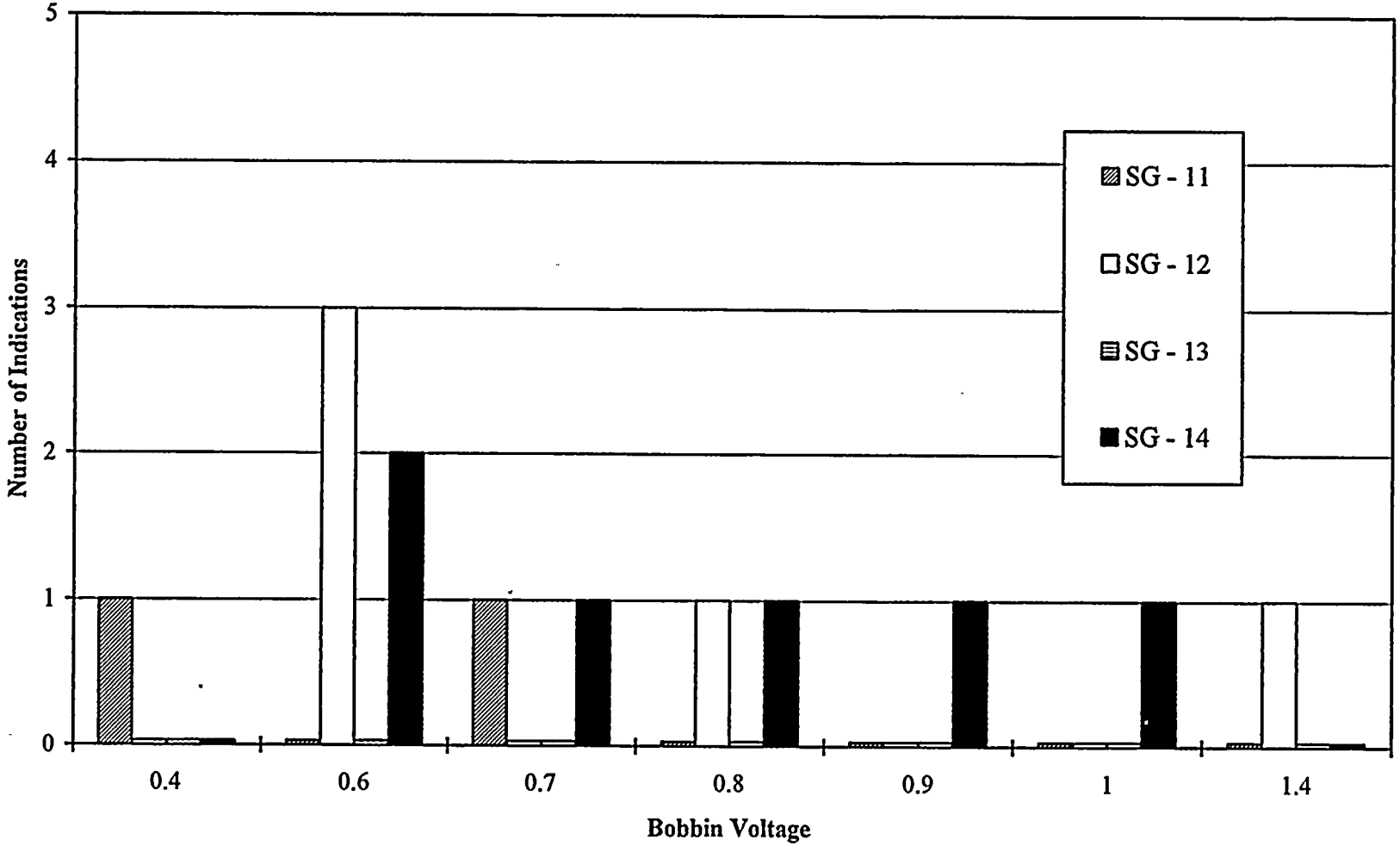


Figure 3 -3
D. C. Cook Unit -1 1995 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 14 and RTS for Cycle 15

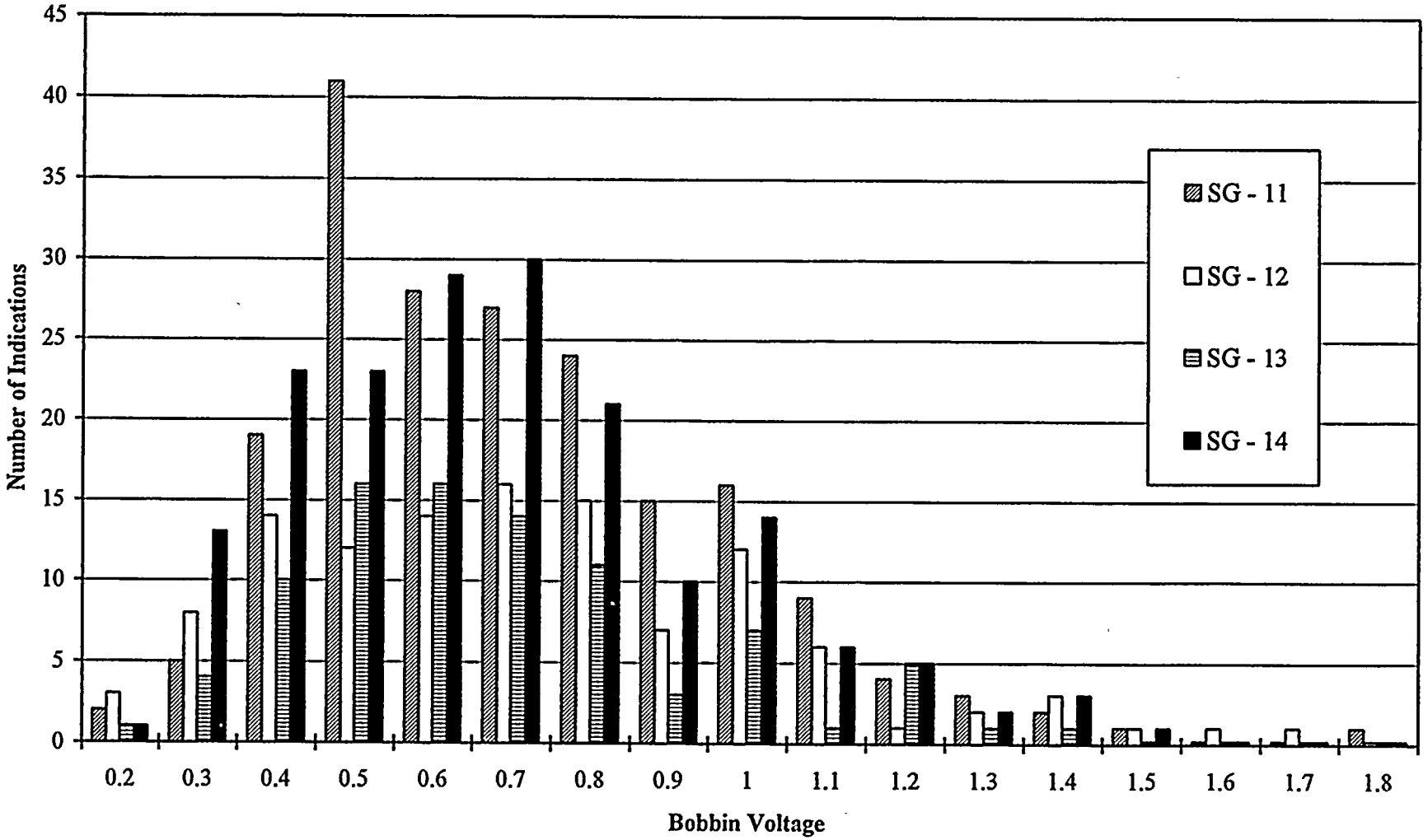


Figure 3 - 4
D. C. Cook Unit -1 1995 Outage
Bobbin Voltage Distributions for Deplugged Tubes Returned to Service for Cycle 15 Operation

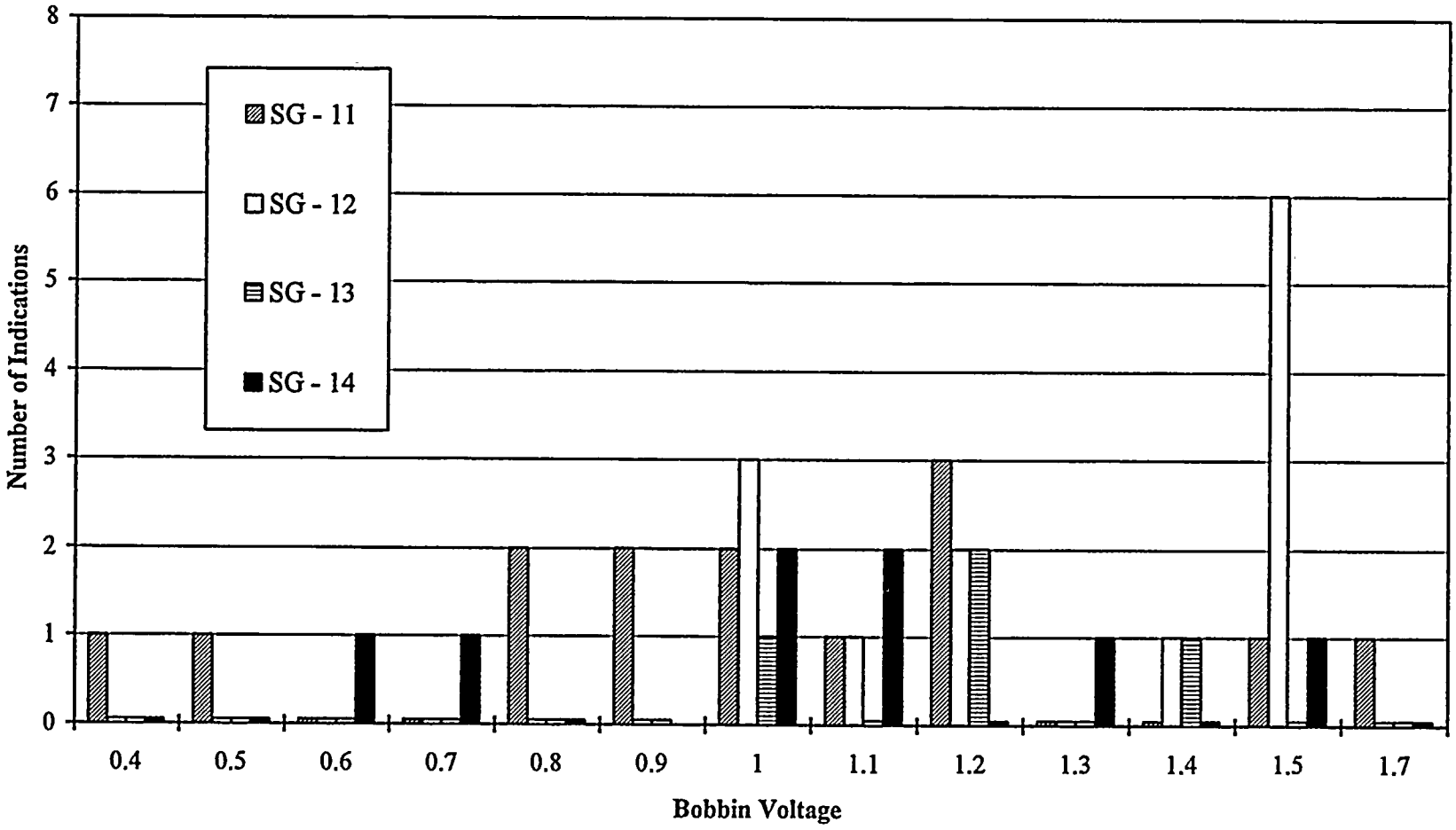


Figure 3 - 5
D. C. Cook Unit -1 1995 Outage
Bobbin Voltage Distributions for All Tubes Returned to Service at BOC-15

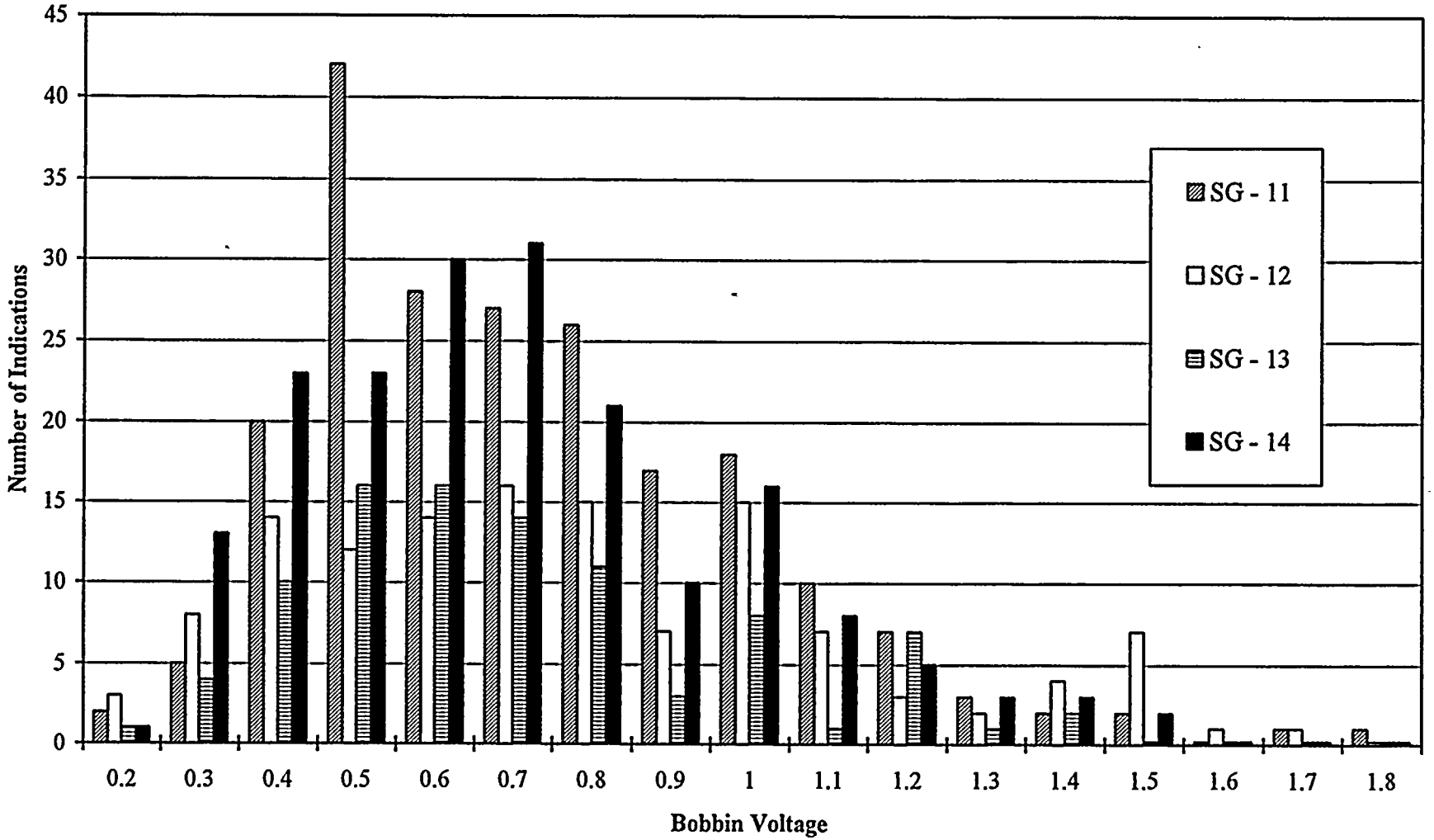


Figure 3 - 6
D. C. Cook Unit 1 1995 Outage
ODSCC Axial Distributions for Tubes in Service During Cycle 14

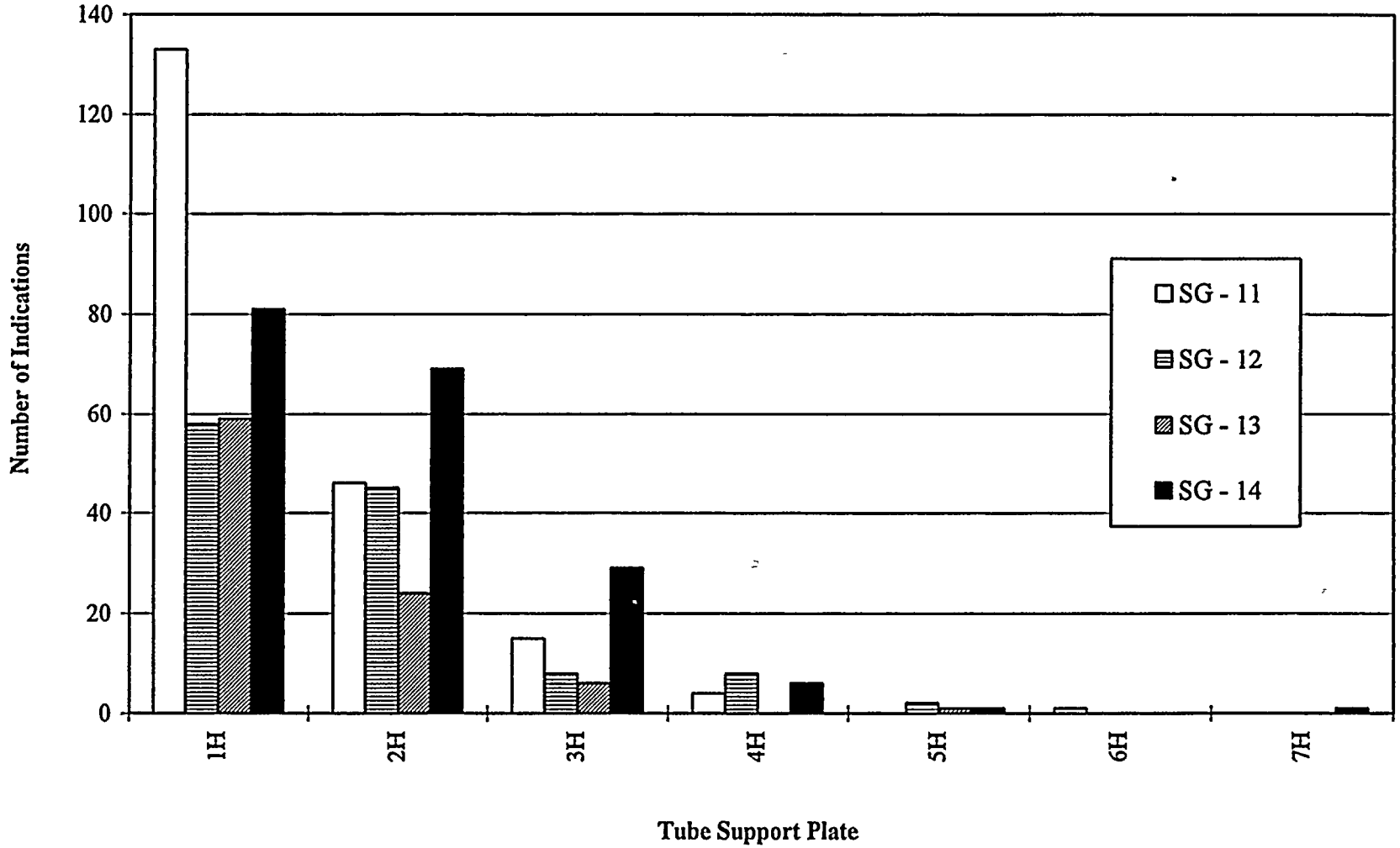


Figure 3 - 7
D. C. Cook Unit - 1
Cumulative Probability Distributions for Voltage Growth History on an EFPY Basis
Composite of All Four Steam Generators

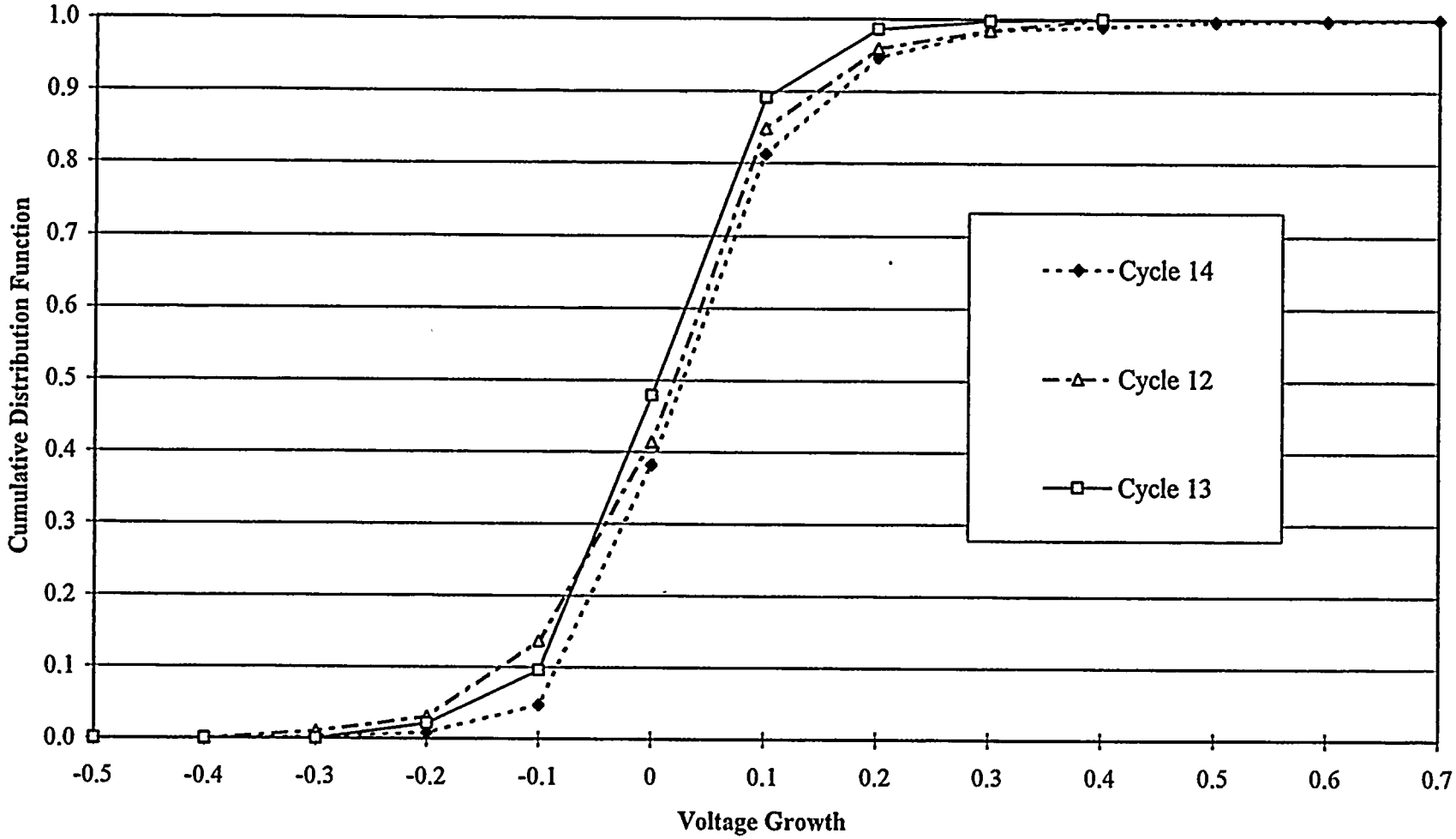
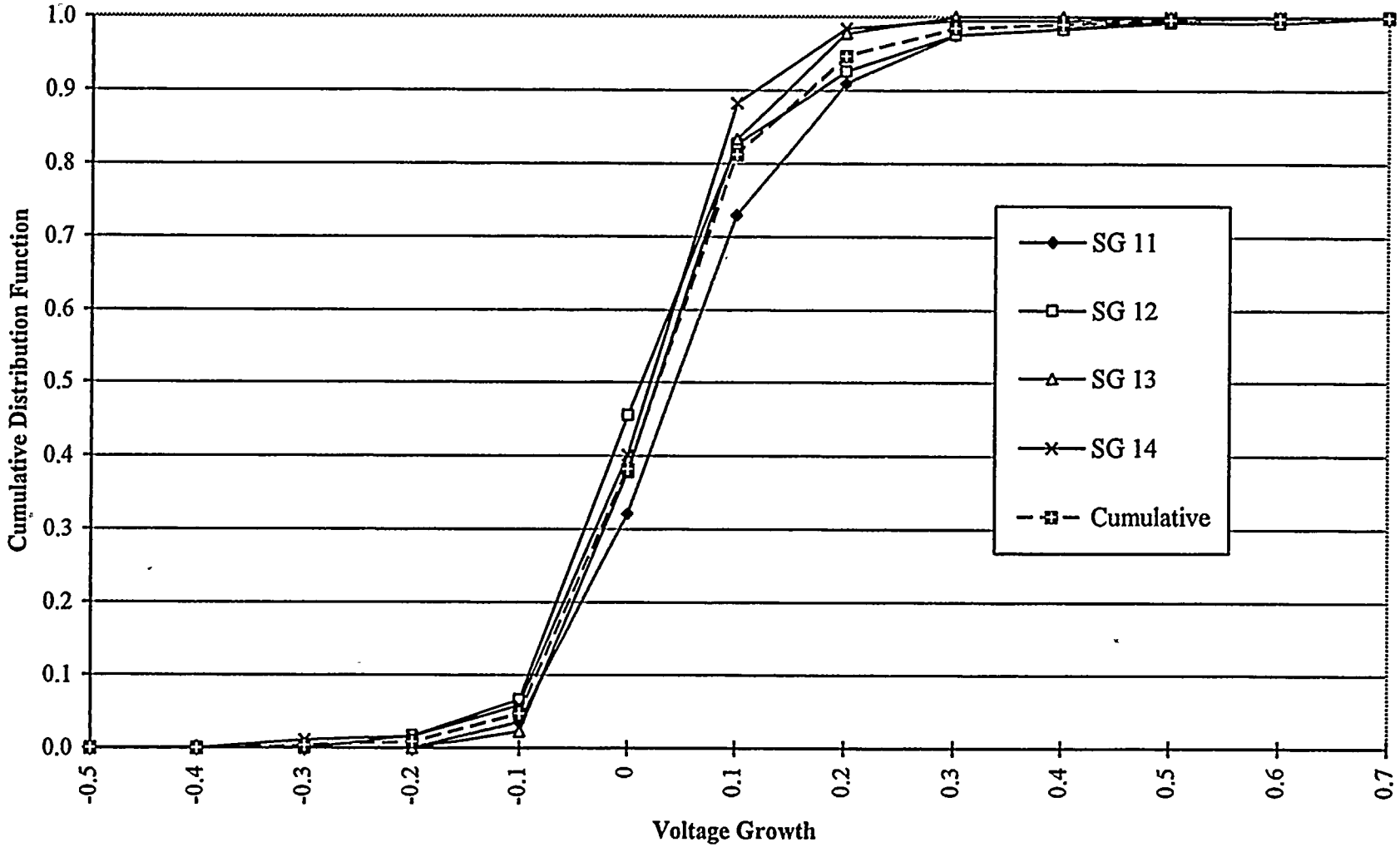


Figure 3 - 8
D. C. Cook Unit -1 Cycle 14 (1994 to 1995)
Cumulative Probability Distributions for Voltage Growth on EFPY Basis



4.0 DATA BASE APPLIED FOR IPC CORRELATIONS

The database used for the IPC correlations that are applied in the analyses of this report are consistent with the NRC SER applicable to the D.C. Cook Unit 1 EOC-14 inspection (documented in Reference 8.3). The SER recommended data for the burst pressure correlation is the same as the EPRI recommended database described in Reference 8.4 and is applied in the analyses of this report.

For the SLB leak rate correlation, the NRC recommends that Model Boiler specimen 542-4 and Plant J-1 pulled tube R8C74, TSP1 be included in the database. This database is referred to as the NRC database in Reference 8.5 (WCAP-14123) and is applied for the leak rate analyses of this report. The probability of leakage correlation of Reference 8.5 (WCAP-14123) is also accepted by the NRC SER and applied in this report. The SLB leak rate data do not satisfy the NRC guidelines for a voltage dependent correlation and, consistent with GL-95-05, the leak rate correlation is developed independent of voltage, as discussed in Section 5.

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators of nuclear power plants which relate bobbin voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 8.2 and 8.5, is consistent with NRC criteria and guidelines of References 8.1 and 8.3.

The analysis process starts with the receipt of bobbin voltage from the site ECT inspection team. The site data consists of electronic files which include Row, Column, TSP identification number, and bobbin voltage. This data, sorted by bobbin voltage into "voltage bins" consisting of number of indications in discrete voltage ranges in increments of 0.1 volt, constitutes one major component of input for the subsequent voltage distribution, leak and burst probability calculations. It is noted that reference to "volts" in this report invariably applies to "voltage bins", when cited to one significant figure after the decimal (e.g., 1.8 volts). The true value of an indication would be cited to two significant figures after the decimal (e.g., 1.71 volts).

The calculation consists of determining the initial conditions (i.e., the bobbin indication population distribution), projecting the indication growth over the operating period, and then evaluating the tube leak and burst probabilities at the end of the operating period. Since indication growth is considered proportional to operating time, the limiting tube conditions occur at the end of any given time period or cycle.

5.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to predict the EOC-15 voltage distributions and to calculate the SLB leak rates and tube burst probabilities for both the actual EOC-14 voltage distribution and the predicted EOC-15 voltage distribution. These methods are consistent with the requirements of the D.C. Cook Unit 1 NRC SER and are described in the generic methods report of WCAP-14277 (Reference 8.2) and the IPC report of WCAP-14123 (Reference 8.5).

Based on the NRC SER recommended leak rate database, the leak rate data do not satisfy the requirement for applying the SLB leak rate versus bobbin voltage correlation. The NRC requirement is that the p value obtained from the regression for the slope parameter be less than or equal to 5%. For the NRC recommended data, the p value is about 6.5% and the leak rate versus voltage correlation is not applied. The SLB leak rate correlation applied is based on an average of all leak rate data independent of voltage. The analysis methods for applying this leak rate model are given in Section 4.6 of WCAP-14277. A Monte Carlo analysis is applied to account for parameter uncertainties even though the leak rate is independent of voltage. This method of leak rate analysis is similar to that of draft NUREG-1477 except for the uncertainty treatment.

6.0 BOBBIN VOLTAGE DISTRIBUTIONS

6.1 PROBABILITY OF DETECTION (POD)

The number of bobbin voltage indications used to predict tube leak rate and burst probability is obtained by adjusting the number of reported indications to account for measurement uncertainty and confidence level in voltage correlations. This is accomplished by using a Probability of Detection (POD) factor. Adjustments are also made for indications either removed from or returned to service. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as:

$$N_{Tot\ RTS} = \frac{N_i}{POD} - N_{Repaired} + N_{deplugged},$$

where:

$N_{Tot\ RTS}$ = Number of bobbin indications being returned to service for the next cycle.

N_i = Number of bobbin indications (in tubes in service during the previous cycle) reported in the current inspection.

POD = Probability of Detection.

$N_{repaired}$ = Number of N_i which are repaired (plugged) after the last cycle.

$N_{deplugged}$ = Number of previously-plugged indications which are deplugged after the last cycle and are returned to service.

The NRC generic letter (Reference 8.1 is the draft of GL-95-05) requires the application of a POD = 0.6 to define the BOC distribution for the EOC voltage projections, unless an alternate POD is approved by the NRC.

6.2 CYCLE OPERATING TIME

The operating periods used in the voltage projection calculations are:

Cycle 12 = 455. EFPD. Cycle 13 = 444.2 EFPD. Cycle 14 = 390.54 EFPD.

Cycle 15 = 425. EFPD (Normal Burnup) or 465. EFPD (With Power Coastdown).

6.3 CALCULATION OF VOLTAGE DISTRIBUTIONS

Bobbin voltage projections start with a cycle initial voltage distribution which is projected to the corresponding cycle final voltage distribution, based on the growth rate adjusted for the anticipated cycle operating time period. The overall growth rates for each of the D.C. Cook Unit 1 steam generators during the previous two operating periods, as represented by their cumulative probability distribution

functions, are shown on Figure 3-7. The 1994 - 1995 operation (Cycle 14) growth rates exceed those of the 1993 - 1994 (Cycle 13) operation and are used to predict the EOC-15 bobbin voltage distributions. Further conservatism for the EOC-15 bobbin voltage prediction is provided by the use of a limiting voltage growth hybrid envelope described in Section 3.2, for the voltage projections of each SG. The methodology used in the calculations of EOC bobbin voltage distributions is described in References 8.2 and 8.4.

For each SG, the initial bobbin voltage distribution of indications being returned to service for the next cycle (BOC-15) is derived from the actual EOC-14 inspection results adjusted for tubes that are either (a) taken out of service by plugging, or (b) have been recovered for Cycle 15 service by deplugging of tubes plugged in previous outages on the basis of prior repair criteria. The Cycle 15 bobbin voltage population, summarized on Table 6-1, shows EOC-14 bobbin voltage indications; the subsequent plugged indications (which were in service for Cycle 14 and then taken out of service, albeit not for reasons of ODSCC at TSP); those indications recovered for service from previously plugged tubes, which were deplugged during this outage and were inspected and returned to service in accordance with IPC criteria (otherwise they were replugged); and also shows the BOC-15 indications corresponding to PODs of 0.6, 1.0, and the EPRI lower 95% confidence limit.

6.4 PREDICTED EOC-15 VOLTAGE DISTRIBUTIONS

Calculation of the predicted EOC-15 bobbin voltage distributions is performed for all SGs with three different detection factors represented by:

POD = 0.6, in accordance with NRC direction.

POD = EPRI, a voltage based probability developed by EPRI.

POD = 1.0, a nominal value with no uncertainty considered.

Using the methodology previously described, analyses were performed to predict the performance of the D.C. Cook Unit 1 steam generators at EOC-15, based on the BOC-15 summarized in Table 6-1 and the Cycle 14 hybrid growth distribution summarized in Table 3-8 (in accordance with NRC guidelines, Cycle 14 growth is used since it is the higher of the last two cycles). The EPRI developed voltage dependent POD is based on expert opinion and multiple analysts' evaluations for plants with 3/4" diameter tubes. It is of interest to apply the EPRI POD for sensitivity analysis and for comparison with POD = 0.6 and POD = 1.0. The BOC-15 IPC voltage distributions are summarized on Table 6-1 for POD = 0.6, for the EPRI POD and for POD = 1.0, which is the order of decreasing detection uncertainty. The corresponding EOC-15 predicted IPC voltage distributions are summarized on Table

6-2. The POD = 0.6 is sufficiently small to conservatively account for both undetected and new indications formed during the next operating cycle. Since the net adjustment from the POD is applied to obtain the BOC distribution, the number of indications does not further increase over the operating cycle. As anticipated, the limiting steam generator is SG 11 with 344 indications predicted for POD = 0.6. For each steam generator, the BOC-15 actual and the EOC-15 predicted bobbin voltage frequency distributions are shown on Figure 6-1, 6-2, 6-3, and 6-4, respectively, for all three PODs. The maximum bobbin voltage predicted for EOC-15 is 2.4 V for POD = 0.6, in SG 11 and SG 12.

6.5 COMPARISON OF PREDICTED AND ACTUAL EOC-14 VOLTAGE DISTRIBUTIONS

The actual EOC-14 bobbin voltage distributions and the corresponding predictions, summarized on Table 6-3 and shown on Figures 6-5 and 6-6, provide a comparison of detection probability factors represented by the two PODs used in the EOC-14 predictions. As reported in Reference 8.6, SG 14 was predicted to be limiting for EOC-14. As shown on Figure 6-5, the POD = 0.6 calculation overpredicted the actual SG 14 EOC-14 bobbin voltage population distribution, except for the 0.3 and 0.4 volt bins where the population was underpredicted. As shown on Figure 6-6, the POD = 1.0 calculation underpredicted the actual bobbin voltage population distribution in five out of six bins below 0.8 V and over-predicted in eight out of ten above 0.8 V. The overprediction in the higher volt range demonstrates the conservatism in the growth rate distribution used for the prediction. The predicted bobbin voltages of 2.0 V and 1.9 V for POD = 0.6 and 1.0, respectively, are conservative relative to the actual measured bobbin voltage indication of 1.5 V in SG 14. The actual EOC-14 bobbin voltage for SG 11, which turned out to be the limiting SG at EOC-14 by a small margin, is also shown on Table 6-3 and on Figure 6-5 and Figure 6-6.

TABLE 6-1
D. C. Cook Unit 1 1995 Outage
Summary of Inspection and Repair of Tubes

Voltage Bin	STEAM GENERATOR 11						STEAM GENERATOR 12					
	EOC-14			BOC-15			EOC-14			BOC-15		
	Field Ind.	Plug Ind.	Deplug RTS	POD =0.6	POD= EPRI	POD =1.0	Field Ind.	Plug Ind.	Deplug RTS	POD =0.6	POD= EPRI	POD =1.0
0.10	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0
0.20	2	0	0	3.3	6.3	2	3	0	0	5.0	9.4	3
0.30	5	0	0	8.3	11.6	5	8	0	0	13.3	18.6	8
0.40	20	1	1	33.3	37.0	20	14	0	0	23.3	25.9	14
0.50	41	0	1	69.3	70.9	42	12	0	0	20.0	20.5	12
0.60	28	0	0	46.7	44.2	28	17	3	0	25.3	23.8	14
0.70	28	1	0	45.7	40.2	27	16	0	0	26.7	23.5	16
0.80	24	0	2	42.0	34.9	26	16	1	0	25.7	20.9	15
0.90	15	0	2	27.0	21.2	17	7	0	0	11.7	9.0	7
1.00	16	0	2	28.7	21.7	18	12	0	3	23.0	17.8	15
1.10	9	0	1	16.0	11.7	10	6	0	1	11.0	8.1	7
1.20	4	0	3	9.7	7.6	7	1	0	2	3.7	3.1	3
1.30	3	0	0	5.0	3.3	3	2	0	0	3.3	2.2	2
1.40	2	0	0	3.3	2.2	2	4	1	1	6.7	4.3	4
1.50	1	0	1	2.7	2.1	2	1	0	6	7.7	7.1	7
1.60	0	0	0	0.0	0.0	0	1	0	0	1.7	1.1	1
1.70	0	0	1	1.0	1.0	1	1	0	0	1.7	1.0	1
1.80	1	0	0	1.7	1.0	1	0	0	0	0.0	0.0	0
TOTAL	199	2	14	344	317	211	121	5	13	210	196	129
>1V	20	0	6	39	29	26	16	1	10	19	27	25

Voltage Bin	STEAM GENERATOR 13						STEAM GENERATOR 14					
	EOC-14			BOC-15			EOC-14			BOC-15		
	Field Ind.	Plug Ind.	Deplug RTS	POD =0.6	POD= EPRI	POD =1.0	Field Ind.	Plug Ind.	Deplug RTS	POD =0.6	POD= EPRI	POD =1.0
0.10	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0
0.20	1	0	0	1.7	3.1	1	1	0	0	1.7	3.1	1
0.30	4	0	0	6.7	9.3	4	13	0	0	21.7	30.2	13
0.40	10	0	0	16.7	18.5	10	23	0	0	38.3	42.6	23
0.50	16	0	0	26.7	27.3	16	23	0	0	38.3	39.2	23
0.60	16	0	0	26.7	25.3	16	31	2	1	50.7	47.9	30
0.70	14	0	0	23.3	20.6	14	31	1	1	51.7	45.6	31
0.80	11	0	0	18.3	15.1	11	22	1	0	35.7	29.1	21
0.90	3	0	0	5.0	3.8	3	11	1	0	17.3	13.1	10
1.00	7	0	1	12.7	9.6	8	15	1	2	26.0	19.5	16
1.10	1	0	0	1.7	1.2	1	6	0	2	12.0	9.1	8
1.20	5	0	2	10.3	7.7	7	5	0	0	8.3	5.7	5
1.30	1	0	0	1.7	1.1	1	2	0	1	4.3	3.2	3
1.40	1	0	1	2.7	2.1	2	3	0	0	5.0	3.2	3
1.50	0	0	0	0.0	0.0	0	1	0	1	2.7	2.1	2
1.60	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0
1.70	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0
1.80	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0
TOTAL	90	0	4	154.2	144.7	94.0	187	6	8	313.7	293.6	189.0
>1V	8	0	3	16	12	11	17	0	4	32	23	21

TABLE 6-2
D. C. Cook Unit 1 1995 Outage
Summary of Predicted Bobbin Voltage Distributions for EOC-15

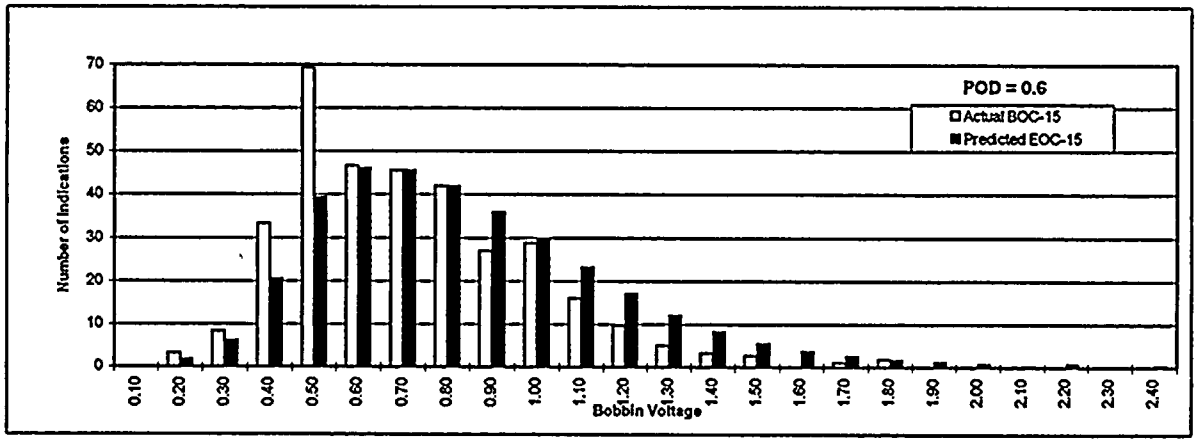
Voltage Bin	STEAM GENERATOR 11			STEAM GENERATOR 12		
	POD = 0.6	POD = EPRI	POD = 1.0	POD = 0.6	POD = EPRI	POD = 1.0
0.1	0.1	0.1	0.0	0.1	0.2	0.1
0.2	1.7	3.1	1.0	2.6	4.7	1.6
0.3	6.1	8.5	3.7	8.1	11.6	4.8
0.4	20.5	23.4	12.3	14.8	18.0	8.9
0.5	39.4	41.4	23.8	18.5	20.4	11.0
0.6	46.1	46.0	27.8	21.6	21.7	12.6
0.7	45.7	43.0	27.5	23.5	21.9	13.7
0.8	42.0	37.4	25.4	22.8	20.1	13.4
0.9	36.0	30.5	22.1	20.6	17.3	12.3
1.0	29.6	24.1	18.4	17.9	14.5	11.0
1.1	23.1	18.3	14.5	14.5	11.5	9.1
1.2	17.0	13.2	10.8	11.1	8.7	7.1
1.3	12.0	9.3	7.7	8.5	6.5	5.6
1.4	8.2	6.3	5.3	6.7	5.2	4.6
1.5	5.5	4.1	3.6	5.5	4.3	3.9
1.6	3.7	2.7	2.4	4.4	3.4	3.1
1.7	2.5	1.8	1.7	3.2	2.5	2.3
1.8	1.7	1.2	1.1	2.2	1.7	1.6
1.9	1.1	0.8	0.8	1.4	1.1	1.0
2.0	0.7	0.3	0.3	0.8	0.5	0.4
2.1	0.1	0.0	0.0	0.1	0.0	0.0
2.2	0.7	0.7	0.7	0.7	0.7	0.7
2.3	0.0	0.3	0.3	0.0	0.3	0.3
2.4	0.3	0.0	0.0	0.3	0.0	0.0
TOTAL	344	317	211	210	196	129
>1V	77	59	49	59	46	40

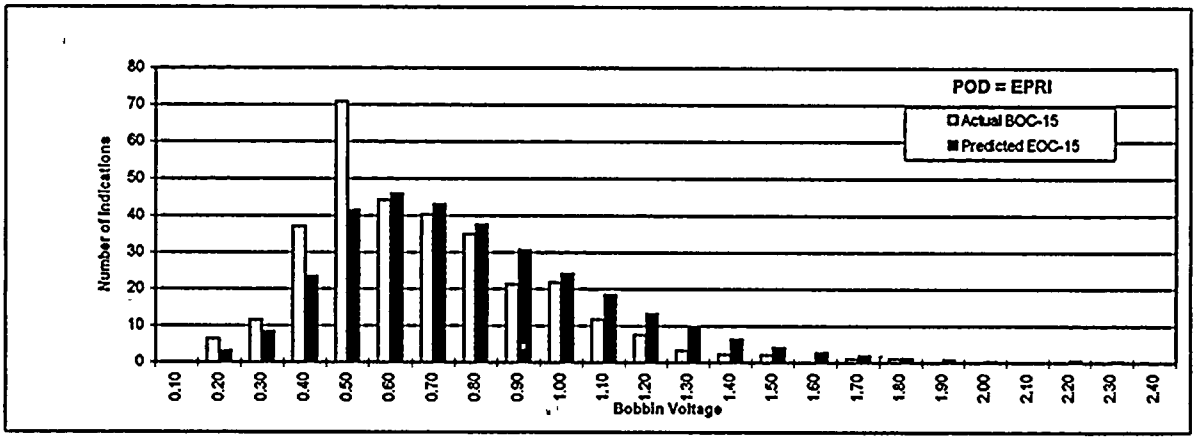
Voltage Bin	STEAM GENERATOR 13			STEAM GENERATOR 14		
	POD = 0.6	POD = EPRI	POD = 1.0	POD = 0.6	POD = EPRI	POD = 1.0
0.1	0.0	0.1	0.0	0.0	0.1	0.0
0.2	0.9	1.7	0.6	1.5	2.4	0.9
0.3	4.1	5.6	2.4	11.2	15.2	6.7
0.4	10.4	12.1	6.2	23.7	28.1	14.2
0.5	17.7	18.8	10.6	32.7	35.4	19.6
0.6	21.9	21.8	13.2	40.5	40.4	24.1
0.7	22.2	20.9	13.3	43.4	40.6	25.9
0.8	19.2	17.2	11.5	39.1	34.8	23.3
0.9	14.8	12.7	9.0	31.9	27.1	19.0
1.0	11.3	9.3	6.9	25.3	20.5	15.2
1.1	8.9	7.0	5.5	19.3	15.2	11.8
1.2	7.0	5.5	4.5	14.3	11.1	8.8
1.3	5.4	4.2	3.5	10.4	7.9	6.5
1.4	3.9	3.0	2.6	7.3	5.5	4.6
1.5	2.6	2.0	1.7	5.0	3.7	3.2
1.6	1.6	1.2	1.1	3.3	2.4	2.1
1.7	0.9	0.5	0.4	2.0	1.5	1.3
1.8	0.1	0.0	0.0	1.2	0.9	0.8
1.9	0.7	0.7	0.7	0.5	0.1	0.0
2.0	0.0	0.3	0.3	0.0	0.7	0.7
2.1	0.3	0.0	0.0	0.7	0.0	0.0
2.2	0.0	0.0	0.0	0.3	0.3	0.3
TOTAL	154	145	94	314	294	189
>1V	32	24	20	64	49	40

Table 6-3
D.C. Cook Unit 1 1995 Outage
Comparison Of Predicted And Actual
EOC-14 Bobbin Indication Population

Voltage Bin	Number Of Indications			
	SG 14			SG 11
	Predicted (Reference 8.6)		Actual	Actual
	POD = 0.6	POD = 1.0		
0.1				
0.2	1	1	1	2
0.3	6	3	13	5
0.4	20	12	23	20
0.5	33	19	23	41
0.6	36	21	31	28
0.7	40	24	31	28
0.8	37	22	22	24
0.9	30	18	11	15
1.0	25	14	15	16
1.1	18	11	6	9
1.2	13	7	5	4
1.3	7	5	2	3
1.4	5	2	3	2
1.5	2	2	1	1
1.6	2	1		
1.7	1			
1.8	1	0.7		1
1.9	0.7	0.3		
2.0	0.3			
TOTAL	278	163	187	199

Figure 6-1
D. C. Cook Unit 1 Steam Generator 11
Bobbin Voltage Distributions for Cycle 15





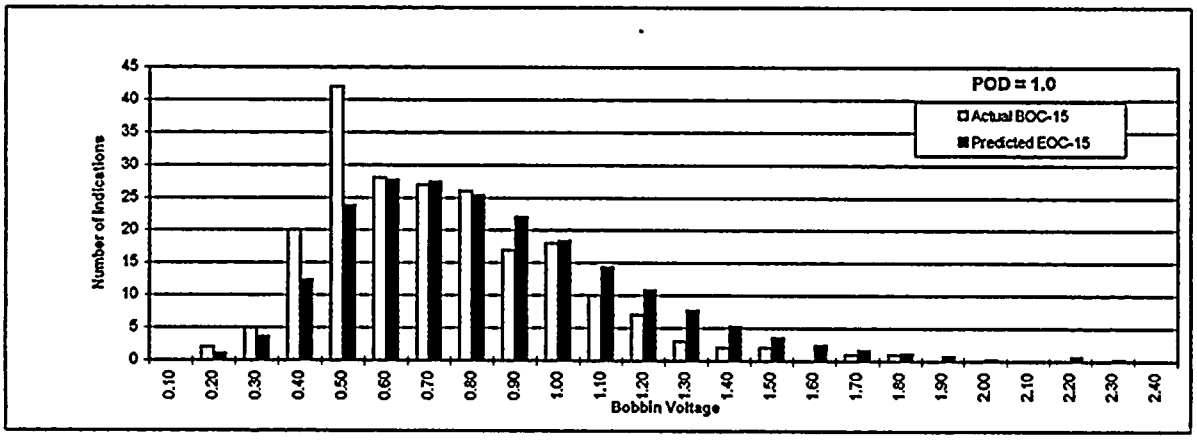
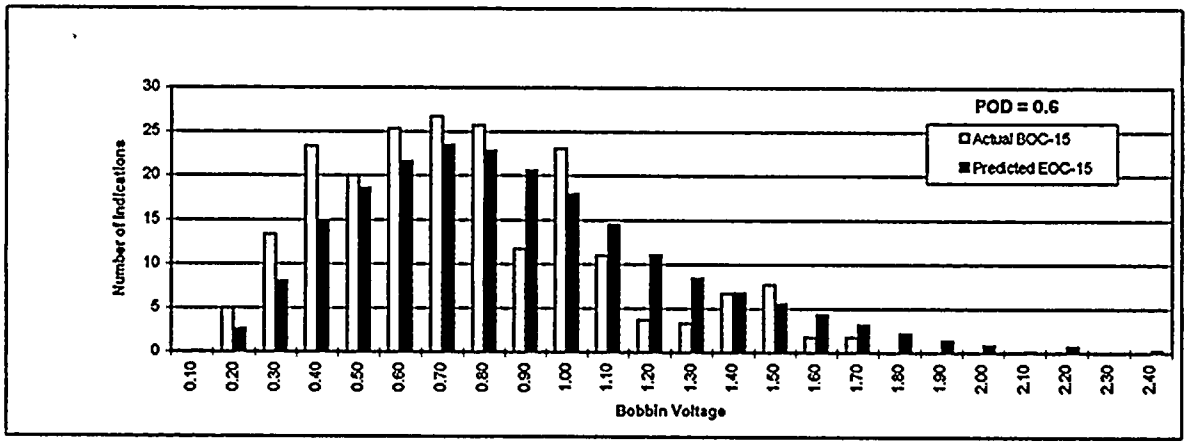
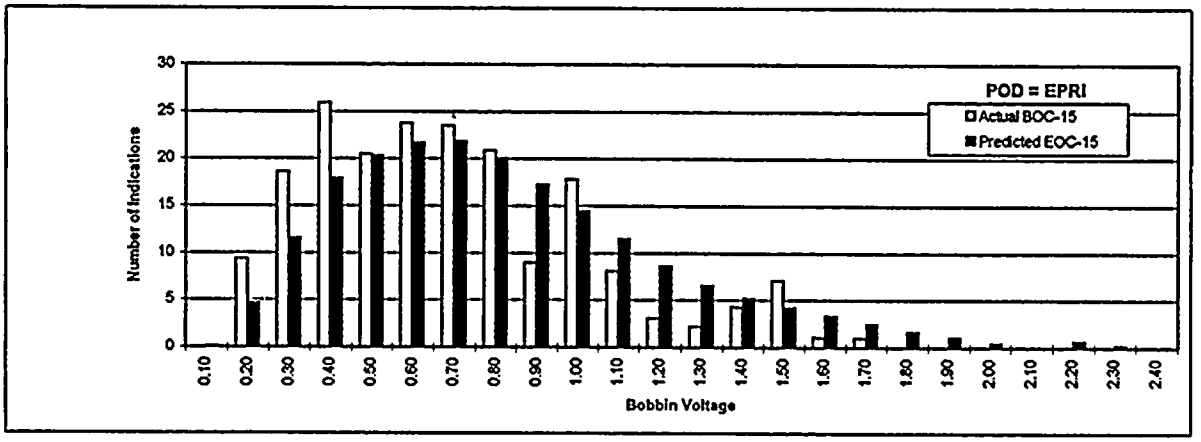


Figure 6-2
D. C. Cook Unit 1 Steam Generator 12
Bobbin Voltage Distributions for Cycle 15





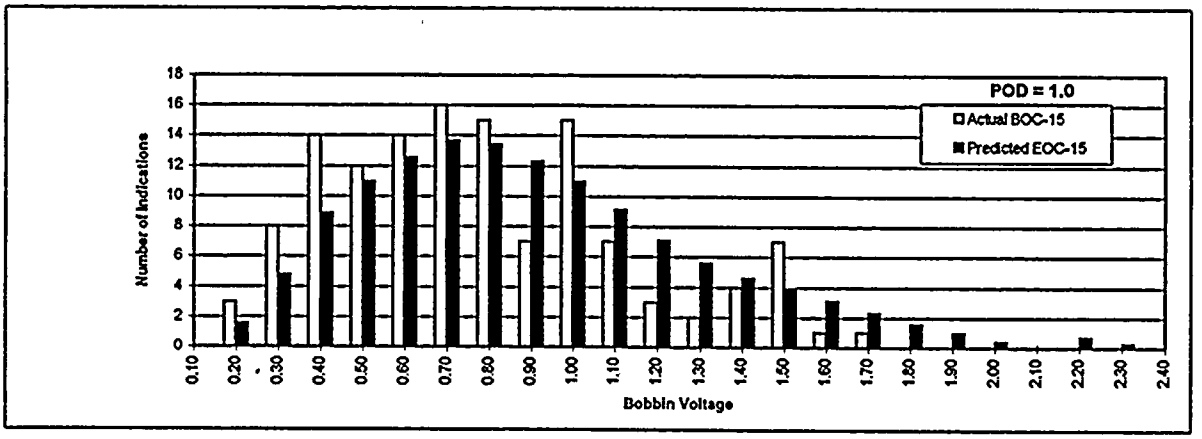


Figure 6-3
D. C. Cook Unit 1 Steam Generator 13
Bobbin Voltage Distributions for Cycle 15

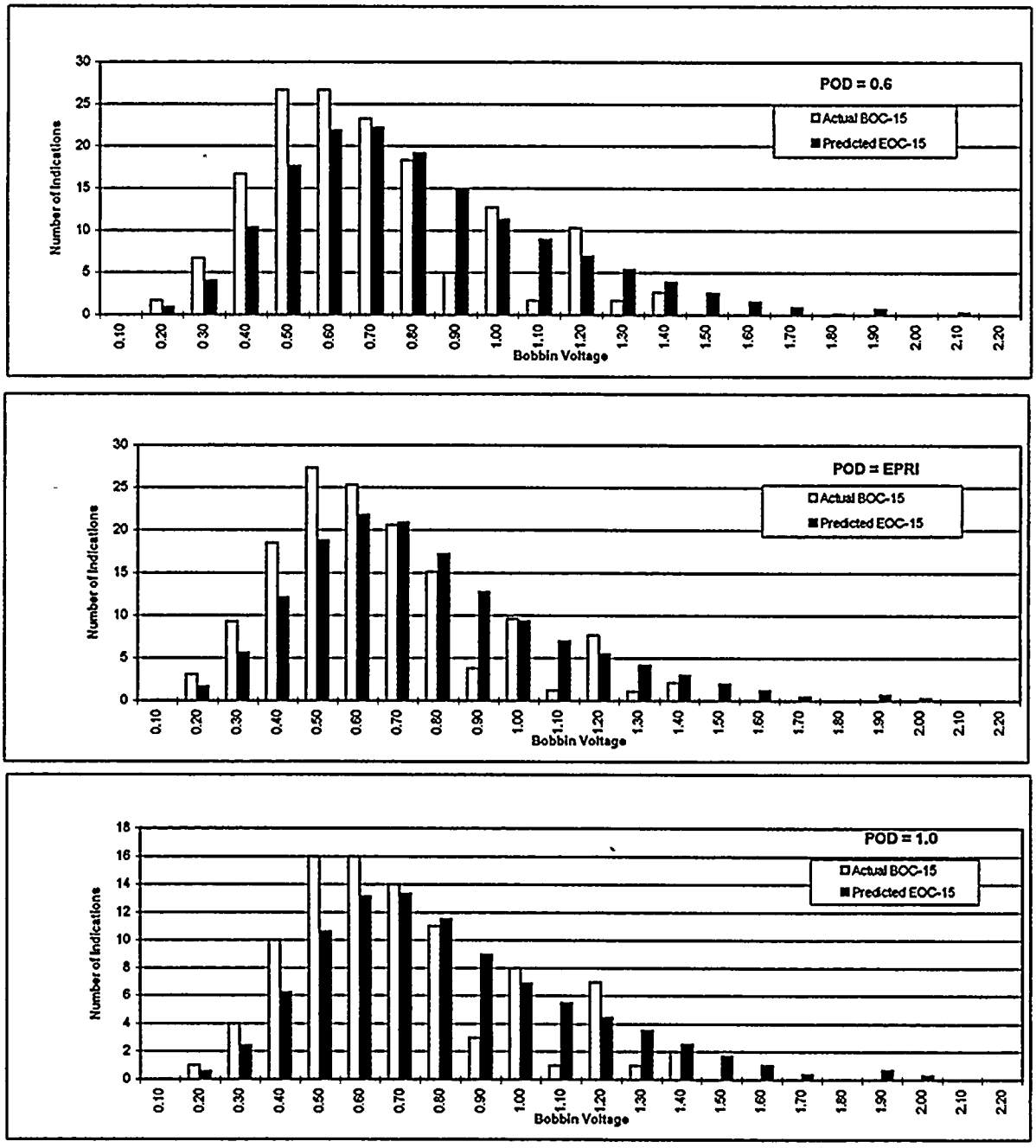


Figure 6-4
D. C. Cook Unit 1 Steam Generator 14
Bobbin Voltage Distributions for Cycle 15

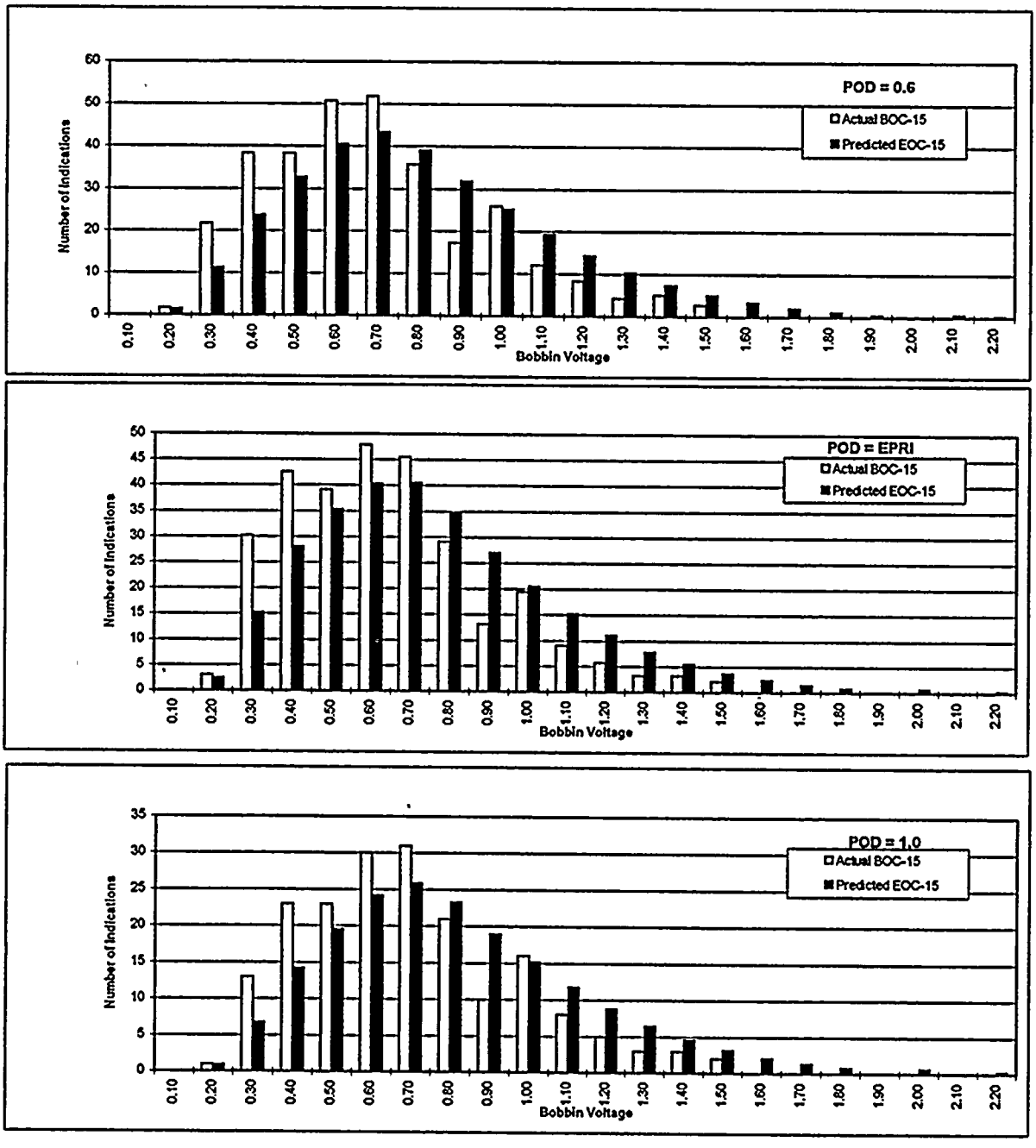


Figure 6-5
D.C. Cook-1 EOC-14
Comparison of Actual vs. Predicted (POD=0.6) Bobbin Voltage Distributions

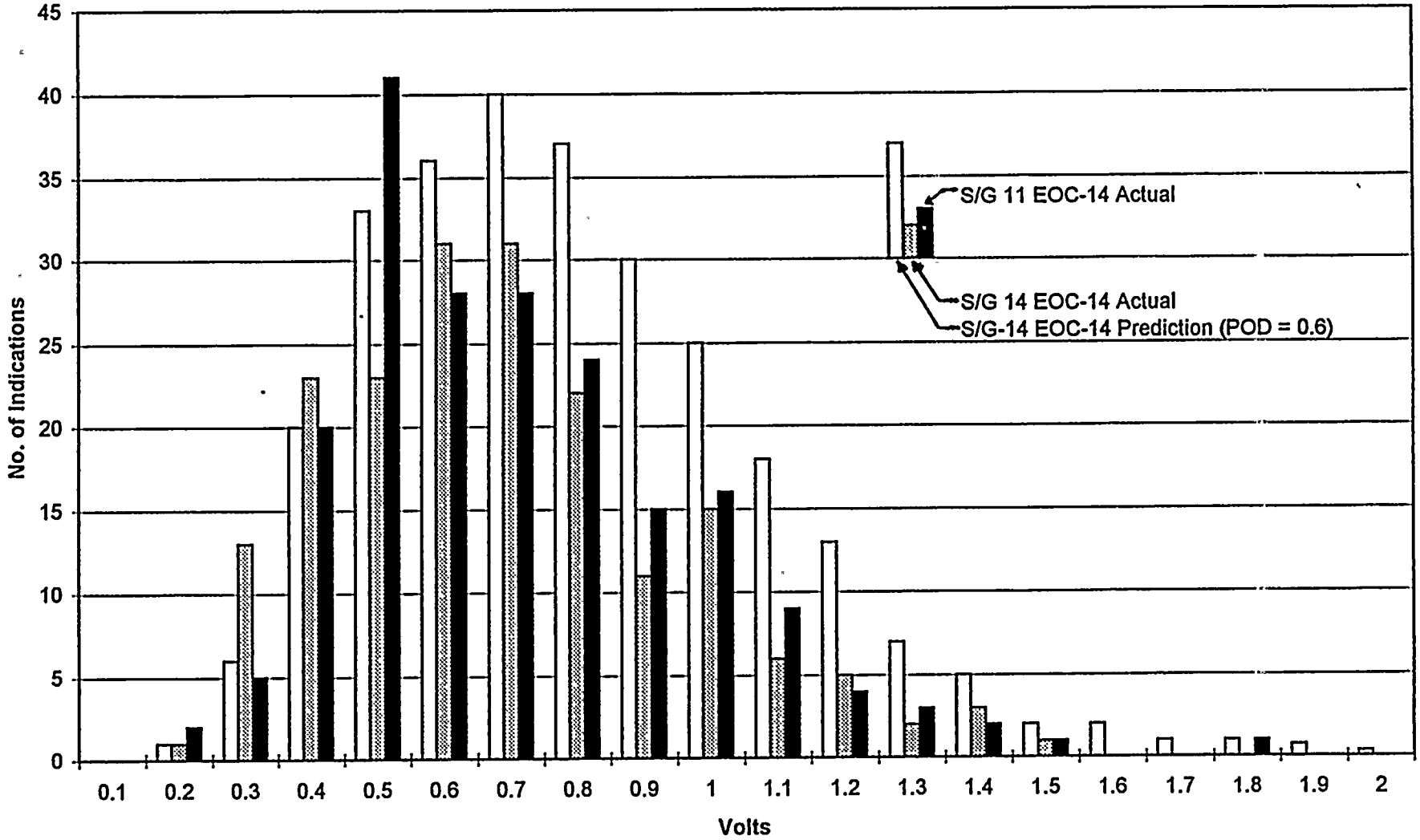
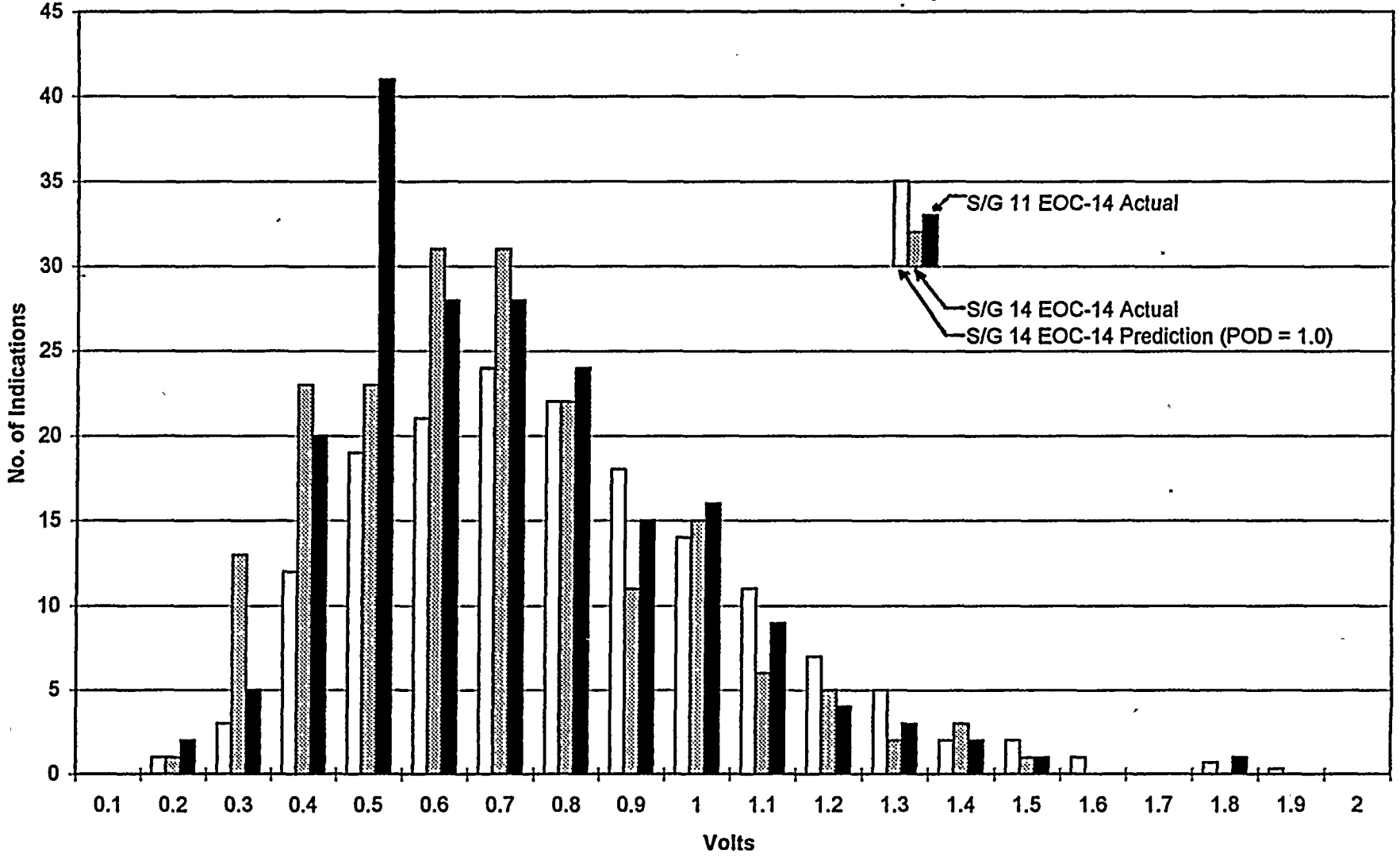


Figure 6-6
D.C. Cook-1 EOC-14
Comparison of Actual vs. Predicted (POD=1.0) Bobbin Voltage Distributions



7.0 TUBE LEAK RATE AND TUBE BURST PROBABILITIES

7.1 CALCULATION OF LEAK RATE AND TUBE BURST PROBABILITIES

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators of nuclear power plants which relate bobbin voltage amplitudes (either measured or calculated), free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 8.2 and 8.4, is consistent with NRC criteria and guidelines of References 8.1 and 8.3.

7.2 PREDICTED AND ACTUAL LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-14

Using the methodology previously described, analyses were performed to calculate EOC-14 SLB tube leak rate and probability of burst for the actual bobbin voltage distribution at EOC-14 (with no growth projection applied) previously presented in this report. The results of Monte Carlo calculations performed for the actual voltage distributions are compared to the prior prediction reported in Reference 8.6, as shown on Table 7-1. Comparison of the EOC-14 actuals with the corresponding predictions indicates that:

a) SG 14 was predicted to be the most limiting steam generator for Cycle 14.

b) Based on actual ECT bobbin measurements at EOC-14, SG 11 has slightly more total (199 vs 187) as well higher amplitude (2.1 V vs 1.8 V) indications than SG 14.

c) Similarly, the SG 11 tube leak rate (0.23 gpm) during a postulated SLB at EOC-14 is lower than predicted for the required POD=0.6 for SG 14 (0.44 gpm), although the distinction is not significant at such low leakrates. The SLB leak rate of 0.23 gpm calculated from the actual EOC-14 voltage distribution is well below the D.C. Cook Unit 1 allowable limit of 12.6 gpm.[1]

d) The EOC-14 probability of burst prediction of 1.9 E-05 (1.6 E-03 for previously used different database) is conservative compared to that based on actual ECT bobbin measurements (< 4.0 E-06) and well below the NRC reporting threshold of 1.0 E-2.

Table 7-1 includes a current recalculation of the EOC-14 prediction (which was performed in the spring of 1994) using the same initial (input) conditions as in 1994 but current methodology and database. The methodology of Reference 8.6 used in the original EOC-13 prediction has been enhanced by methods development represented by Reference 8.2. In addition, the database for the recalculation uses the current NRC approved data and exclusion criteria. This database and methods are consistent

with that applied for the actual EOC-14 analyses. Comparing the 1994 and 1995 EOC-14 predictions, the tube burst probability has decreased from 1.6 E-03 to 1.9 E-05 and the leakage has increased from 0.11 gpm to 0.44 gpm. The updated predictions are conservative relative to the actual EOC-14 results for SG 14.

e) Overall, the EOC-14 predictions based on POD = 1.0 are more accurate than those based on POD = 0.6, when compared to the results based on actual EOC-14 conditions. This suggests that a voltage based POD could more reliably predict tube leakage and probability of burst than a constant value of POD.

7.2 LEAK RATE AND TUBE BURST PROBABILITY FOR EOC-15

Using the methodology previously described, calculations have been conducted to predict the performance of the limiting steam generator in D.C. Cook Unit 1, with the bobbin voltage distributions predicted for EOC-15. Results of the EOC-15 predictions, summarized on Table 7-1, indicate that there are not major differences between the four steam generators during postulated SLB conditions, due to the fact that tube leak rate and burst probability calculational results are low. As shown on Table 7-1, the maximum difference in predicted EOC-15 SLB tube leakage between the four SGs is less than 0.50 gpm, at a given POD. The corresponding range in number of single tube bursts, for all four SG and for all three PODs, varies from one to three, in 250 k Monte Carlo simulations, as shown on Table 7-1. These differences are within the variability between Monte Carlo runs and are not meaningful for the small burst probabilities.

The limiting steam generator for Cycle 15 at D.C. Cook Unit 1 is expected to be SG 11. With the NRC endorsed POD = 0.6, the predicted EOC-15 SLB leak rate for SG 11 is calculated as 0.70 gpm, whereas SG 14 produces 0.59 gpm. The EOC-15 SLB tube burst probability for SG 13 is calculated as 2.9 E-05, whereas SG 14 produces 2.7 E-05. These results are well below the D.C. Cook Unit 1 allowable SLB limit of 12.6 gpm[1] and the NRC reporting guideline for tube burst probability of 1.0 E-02.

[1] An ongoing analysis indicates that the maximum leakage (associated with the off-site dose) may be reduced from 12.6 gpm by about a third, which is still well above the projected SLB IPC leakage and still readily satisfies NRC criteria for IPC.

Table 7-1
D.C. Cook Unit 1 1995 Outage
Summary of SLB Tube Leak Rate and Burst Probability
250,000 Simulations

Steam Generator	POD	No. of Indic-ations	Max.[1] Volts	Burst Probability		SLB Leak Rate gpm
				1 Tube ; Occurences	≥ 2 Tube	
EOC-14 PREDICTED						
14	0.6	278.	2.0	1.6 E-03	-	0.11
14	1.0	163.	1.9	-	-	-
14 recalc	0.6	277.	2.0	1.9 E-05 ; 1	<4 E-06	0.44
14 recalc	1.0	163.	2.0	1.9 E-05 ; 1	< 4 E-06	0.22
EOC-14 ACTUAL						
11	1.0	199.	2.1	< 4.0 E-06 ; 0	< 4.0 E-06	0.23
12	1.0	121.	2.0	1.9 E-05 ; 1	< 4.0 E-06	0.14
13	1.0	90.	1.7	< 4.0 E-06 ; 0	< 4.0 E-06	0.06
14	1.0	187.	1.8	< 4.0 E-06 ; 0	< 4.0 E-06	0.20
EOC-15 PREDICTED						
11	0.6	344.	2.4	1.9 E-05 ; 1	< 4.0 E-06	0.70
11	EPRI	317.	2.3	1.9 E-05 ; 1	< 4.0 E-06	0.57
11	1.0	211.	2.3	2.5 E-05 ; 2	< 4.0 E-06	0.42
12	0.6	210.	2.4	2.3 E-05 ; 1.7	< 4.0 E-06	0.50
12	EPRI	196.	2.3	2.5 E-05 ; 2	< 4.0 E-06	0.39
12	1.0	129.	2.3	3.1 E-05 ; 3	< 4.0 E-06	0.29
13	0.6	154.	2.1	2.9 E-05 ; 2.7	< 4.0 E-06	0.24
13	EPRI	145.	2.0	2.5 E-05 ; 2	< 4.0 E-06	0.19
13	1.0	94.	2.0	2.5 E-05 ; 2	< 4.0 E-06	0.12
14	0.6	314.	2.2	2.7 E-05 ; 2.3	< 4.0 E-06	0.59
14	EPRI	294.	2.2	1.9 E-05 ; 1	< 4.0 E-06	0.47
14	1.0	189.	2.2	2.5 E-05 ; 2	< 4.0 E-06	0.33

[1] Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.

8.0 REFERENCES

8.1 Draft NRC Generic Letter 95-XX, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking", USNRC Office of Nuclear Reactor Regulation, August 1994.

8.2 WCAP-14277, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections", Westinghouse Nuclear Services Division, January 1995.

8.3 U.S. N.R.C. Report, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 200 to Facility Operating License DPR-58 Indiana Michigan Power Company Donald C. Cook Nuclear Plant, Unit No. 1 Docket No. 50-315", September 13, 1995.

8.4 WCAP-13187 (SG-92-03-005), "D.C. Cook Unit 1 Steam Generator Tube Plugging Criteria for ODSCC at Tube Support Plates", Westinghouse Electric Corporation, Proprietary Class 2, March 1992.

8.5 WCAP-14123 (SG-94-07-009), "Beaver Valley Unit 1 Steam Generator Tube Plugging Criteria for Indications at Tube Support Plates July 1994".

8.6 SG-94-05-023, "Cook-1 Cycle 13 IPC Assessment", Westinghouse Nuclear Services Division, June 9, 1994.

THE END

Discard this sheet.

That's all there is.