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COOK-1 CYCLE 13 IPC ASSESSMENT

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COOK-1 CYCLE 13 IPC ASSESSMENT

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1.0 INTRODUCTION

This report provides a Cycle 13 interim plugging criteria (IPC) assessment for the D. C. Cook Unit-1 steam generators. The information requested in the NRC Safety Evaluation Report (Ref. 1) for application of the IPC for Cycle 14 is provided, including comparisons of projected EOC-13 bobbin voltage distributions with actual values found in the EOC-13 inspection, and projections of EOC-14 voltage distributions based on indications left in service at BOC-14. Projected potential steam line break (SLB) leak rates at EOC-14 and tube burst probability at EOC-14 were previously reported in Reference 2, the startup IPC letter report.

The Cook-1 EOC-13 S/G eddy current inspection was the first inspection following implementation of IPC repair limits. Thus the EOC-13 inspection provides an opportunity to compare actual voltage distributions with projected values. BOC-13 indications left in service are used to project EOC-13 voltage distributions for comparison with the actual EOC-13 inspection results. The methods of defining BOC indications include the NRC recommended method of draft NUREG-1477 (Ref. 3) which includes RPC NDD and adjustments for a probability of detection of 0.6, and a distribution including RPC NDD with no adjustment for detection probability.

The Monte Carlo methods of the Cook APC WCAP-13187 (Ref. 4) are applied to the BOC voltage distributions to project the EOC distributions. This is consistent with the NRC guidance given in the Cook-1 SER. S/G 14 is the limiting S/G for SLB leakage and burst considerations for both Cycles 13 and 14 as this S/G has the largest number of indications left in service.

Consistent with the request of the Cook-1 SER, analysis data such as voltage distributions and growth rates are given in both graphical and tabulated form. Table 1-1 relates the data requested in the Cook-1 SER to the report section, table and figure providing the data.

TABLE 1-1

CORRESPONDENCE BETWEEN SER REQUIREMENTS AND REPORT SECTIONS

NRC SER Section 4.5	Subject	Section	Table	Figure
1	EOC 12 voltage distribution - all bobbin ind.	3.1	3-1	3-1a,b
2	Cycle 12 growth rate	5.1	5-2a	5-1
3	EOC 12 repaired indications	4.1	4-1	4-2
4	BOC 13 voltage distribution - all bobbin ind. BOC 13 voltage dist. - draft NUREG-1477	4.1 4.1	4-1 4-1	4-1 4-1
5	BOC 13 voltage dist. - RPC confirmed plus not RPC inspected	4.1	4-1	4-3
6	Cycle 13 NDE uncertainty	6.0	-	-
7	Proj. EOC 13 voltage dist.-WCAP-13187 Proj. EOC 13 voltage dist.-NUREG-1477	7.1 7.1	7-1 7-1	7-1b 7-1a
8	Actual EOC 13 voltage dist.- all bobbin ind. Actual EOC 13 voltage dist.- RPC confirmed plus not RPC inspected	3.2 3.3	3-2 7-1	3-3a,b 7-1a,b
9	Cycle 13 growth rate	5.2	5-2b	5-2
10	EOC 13 repaired ind.	3.2	3-2	3-2, 3-3a,b
11	BOC 14 voltage dist.-all bobbin ind. BOC 14 voltage dist.-draft NUREG-1477	4.2 4.2	4-1 4-1	4-4 4-4
12	BOC 14 voltage dist.-RPC confirmed plus not RPC inspected	4.2	4-1	4-5
13	Cycle 14 NDE uncertainty	6.0	-	-
14	Proj. EOC 14 voltage dist.-WCAP-13187 Proj. EOC 14 voltage dist.-NUREG-1477	7.3 7.3	7-2 7-2	7-3 7-3

2.0 SUMMARY AND CONCLUSIONS

2.1 Overall Conclusions

The distribution of voltages found by inspection at EOC-13 in 1994 is in good agreement with the projections made at EOC-12 in 1992. The agreement between projected and actual voltage distributions found at EOC-13 enhances the confidence in projections made for the end of the next operating cycle (EOC-14). EOC-14 projections were made applying the NRC model of Draft NUREG-1477 to define the BOC distribution with a probability of detection (POD) adjustment factor of 0.6. The voltage growth rates at D. C. Cook-1 continue to be very small with a maximum voltage growth of 0.4 volts for Cycle 13 compared to 0.49 volts for Cycle 12.

Comparisons between projected and actual bobbin voltage distributions at EOC-13 are provided. The draft NUREG-1477 methodology with a POD = 0.6 adjustment to the BOC distribution is conservative compared to the actual voltage distributions.

2.2 1994 EOC-13 Inspection Results

The number of potential flaw indications found in the 1994 inspection was 514 which includes 156 in S/G 11, 103 in S/G 12, 84 in S/G 13 and 171 in S/G 14. The number of RPC confirmed indications was 24 of the 77 potential indications RPC inspected. For indications above 1.0 volt, the RPC confirmation was 18 out of 43 potential bobbin indications RPC inspected. Thus the RPC confirmation rate for potentially repairable bobbin indications above 1.0 volt was 42%. These low confirmation rates are indicative of conservative bobbin indication calling criteria. The largest bobbin indications confirmed by RPC were 1.72, 1.54 and 1.53 volts. A potential bobbin indication at 1.77 volts was not confirmed as a flaw indication by RPC. No tubes were found for which the bobbin voltage exceeded the 2.0 volt IPC repair limit in place for Cycle 14.

2.3 Voltage Growth

The largest voltage growth of 0.40 volts found for Cycle 13 was found in SG-12 R13C66 which had an actual EOC-13 bobbin voltage of 0.96 volts and was not RPC inspected. The largest growth found for an RPC confirmed indication was 0.25 volts. For Cycle 12, the largest growth was 0.49 volts. The Cycle 13 growth rates are lower in average and maximum value compared to prior Cook-1 cycles although the growths for both cycles are among the smallest found for plants evaluated for IPC applications. The average voltage growth was 0.01 volts or 1.4% of the average BOC voltages compared to 0.022 volt (2.2%) growth for Cycle 12.

2.4 Comparison of Projected and Actual EOC-13 Bobbin Voltage Distributions

The 1994 Cook-1 inspection represents the first full cycle of operation following IPC implementation. Thus the resulting data permits comparisons of projected and actual EOC voltage distributions. These comparisons were made applying the NRC draft NUREG-1477 methodology including a POD = 0.6 adjustment to detected indications and a method including RPC NDD indications without a POD adjustment (all bobbin indications left in service) as described in WCAP-13187. The projection

methods are compared with the actual EOC-13 distribution for RPC confirmed indications plus indications not RPC inspected. Since the primary purpose of the voltage projections for IPC/APC applications is to estimate tube leakage and burst probabilities, only indications found to be RPC confirmed (not inspected are conservatively assumed to be confirmed) are used for comparisons with the projected distributions, since RPC NDD indications would not have any significant probability of leakage over the prior cycle.

It is found that the draft NUREG-1477 methodology is quite conservative in the number and magnitude of the EOC-13 indications. The projected maximum voltage is 2.4 volts compared to the actual value of 1.6 volts. It is found that this methodology introduces significant conservatism in the voltage distributions. Results of this evaluation are provided in Section 7.2.

3.0 EOC-12 AND EOC-13 S/G INSPECTION RESULTS

3.1 EOC-12 Inspection Results

EOC-12 inspection results are required in this report to define the BOC-13 indications left in service. This provides the starting point for projecting EOC-13 voltage distributions, which are then compared to the actual EOC-13 inspection results. The 1992 inspection at EOC-13 was the first D.C. Cook-1 inspection implementing an IPC and applied eddy current data collection and analysis guidelines given in Appendix A of WCAP-13187. This included use of ASME calibration standards normalized to the reference laboratory standard and probe wear standards.

Figures 3-1a and 3-1b and Table 3-1 show the S/G 14 and all S/G bobbin indications found at EOC-12 along with the indications confirmed as flaws by RPC inspection. The number of indications found in S/Gs 11, 12 and 13 are fewer than for S/G 14. For Figures 3-1a and 3-1b and all figures given in this report, the voltage values given on the X-axis of the plots represent the upper or right-side value for the voltage bin. Indications above the IPC repair limit of 1.0 volt were 100% RPC inspected, while only a sample of indications below 1.0 volts were inspected. S/G 14 results have been utilized for EOC-13 voltage and leak rate projections based on comparative leak rate calculations which showed S/G 14 to be the most limiting. A total of 149 bobbin indications were found in S/G 14. Above 1.0 volt, 24 indications were found in S/G 14 and 12 were RPC confirmed and removed from service, principally due to confirmation as flaws by RPC. A total of 467 bobbin indications were found in all four S/Gs, 87 of these indications had bobbin voltages > 1.0 volt and 65 of the 87 indications were confirmed by RPC. S/Gs 11, 12 and 13 had 144, 112 and 62 indications, respectively. The indications left in service at BOC-13 are discussed in Section 4.1.

The largest bobbin voltage found in the inspection was 2.0 volts at S/G-12 R18C21 1H. RPC inspection confirmed the flaw indication on this tube. The next largest bobbin voltage was 1.95 volts at S/G 14 R30C13 1H which was also confirmed as a flaw by RPC inspection.

No indications at TSPs were identified as having cracks extending outside the TSPs by either the bobbin or RPC inspections. In addition, no abnormal indications such as circumferentially-oriented indications were found in the 1992 inspection.

3.2 EOC-13: Summary of Indications at TSPs

The 1994 inspection at EOC-13 was completed in March, 1994. This inspection is the first D. C. Cook-1 inspection following implementation of an IPC which permitted leaving indications of 1.0 volt or less in service for indications at TSPs. For this reason, the results of the inspection are evaluated for IPC methodology considerations including comparisons between projected and actual indications in this report. The 1994 bobbin indications were classified as possible indications (PIs), indications not reportable (INRs) and unusual OD phase angles (UOAs). The PIs are considered bobbin flaw indications. If a PI was RPC inspected, the indication was finally classified as a PCN (possible indication confirmed but not pluggable) if confirmed by RPC but not pluggable or a PIN if not confirmed by RPC. INRs are not considered as bobbin flaw indications and this classification is typically assigned to bobbin PIs from a prior inspection that are not considered as a potential flaw indication in the 1994 inspection. UOAs are also not considered as potential flaw indications and this classification is assigned to indications with some flaw-like appearance but the phase angle is larger

than the 0% depth angle from calibration against the ASME standards. Indications in the ID phase angle range are included as PIs as prior RPC inspections have indicated that some ID phase angle indications are confirmed as flaws by RPC inspection. The INRs and UOAs are not included in the bobbin flaw distributions in this report. These classifications are made to permit tracking of these types of signals between inspections and to include some of these indications in the RPC sampling plan to reconfirm that they should not be considered as flaw indications. This section summarizes the inspection results.

A summary of the inspection results are given in Table 3-2. Figure 3-2 shows the total for all 4 S/Gs of all bobbin indications, RPC confirmed indications and repaired indications. Figures 3-3a and 3-3b show the corresponding data for S/Gs 11 and 14, respectively. S/G 14 with 163 indications left in service at BOC-14 is the limiting S/G for SLB leakage analyses. Only a small fraction of the bobbin indications below 1.0 volt were RPC inspected. No indications exceeded the approved 2.0 volt IPC repair limit for this inspection. A few tubes with indications at TSPs were removed from service due to other causes. Based on Table 3-2, the total number of potential flaw indications summed over all 4 S/Gs is 514 which includes 156 in S/G 11, 103 in S/G 12, 84 in S/G 13 and 171 in S/G 14. The total number of RPC confirmed potential flaw indications above 1.0 volt is 18 out of about 43 indications RPC inspected for an RPC confirmation rate of about 42%. Below 1.0 volt, 6 out of 34 indications RPC inspected were confirmed for a confirmation rate of 18%. Table 3-2 includes the distribution of RPC confirmed indications and repaired indications as well as the total bobbin voltage distribution. A total of 22 indications were repaired including 8 in the limiting S/G 14.

Table 3-3 provides a summary of the largest bobbin voltage indications found in the current inspection. RPC inspection results, voltages at the prior inspection and whether or not it is a new indication not reported at the last inspection are also included in Table 3-3. The largest bobbin voltage indications found in 1994 were 1.77 and 1.72, and 1.54 volts in S/G 12, 1.53 volts in S/G 11 and 1.52 volts in S/G 14. For S/G 12, the largest bobbin indication of 1.77 volts was found to be RPC NDD and had also been RPC NDD in the 1992, EOC-12 inspection. The largest RPC confirmed indication of 1.72 volts in S/G 12 in 1994 was not RPC inspected in the 1992, EOC-12 inspection (an abnormal signal with a field voltage of 0.79 volts), and found to have a low voltage (0.20) RPC indication in the current inspection. The largest new indication (not reported in 1992 inspection) confirmed by RPC was the 1.53 volt indication in S/G 11. All bobbin indications found in the EOC-13 inspection were less than the 2.0 volt repair limit such that no tubes required repair due to indications at the TSP intersections. Of the 5 new indications in Table 3-3, 2 were RPC confirmed and 3 were RPC NDD.

3.3 EOC-13 Distributions for Comparisons with Projections

Voltage projections from BOC to EOC conditions for IPC/APC applications are performed to estimate SLB leakage and burst probability. Thus the desired EOC voltages are those having significant potential for throughwall cracks or leakage. Indications that are RPC NDD at EOC can be expected to have negligible potential for leakage over the prior cycle as RPC detectability (as well as bobbin detectability) approaches 100% for ODSCC at TSPs with near throughwall or throughwall indications. It can be noted that the confidence for no leakage over the prior cycle for RPC NDD is higher than the judgement for leakage potential over the next cycle from RPC indications left in service (i.e. the NRC requirement to include RPC NDD in projected leakage analyses). Therefore, for comparisons of projected EOC-13 voltage distributions to be used in leakage analyses with actual distributions, the appropriate actual EOC-13 voltage distribution is the sum of RPC confirmed indications and bobbin

indiçations not RPC inspected (below 1.0 volt for D. C. Cook-1). These distributions are shown in Figure 7-1a and 7-1b for S/G 14 which is the limiting S/G for SLB leakage analyses for both Cycles 13 and 14. The S/G 14 actual distributions of Figures 7-1a and 7-1b for EOC-13 are discussed with projections from BOC-13 to EOC-13 in Section 7.

Table 3-1
EOC-12 Voltage Distribution and RPC Confirmation for SG-14 and All SGs

Voltage	All SGs No. of Indications	All SGs RPC Confirmed Indications	SG-14 No. of Indications	SG-14 RPC Confirmed Indications
0.1	0	0	0	0
0.2	0	0	0	0
0.3	16	0	4	0
0.4	40	0	13	0
0.5	45	0	14	0
0.6	66	0	17	0
0.7	44	0	13	0
0.8	47	0	18	0
0.9	68	3	28	1
1.0	54	0	18	0
1.1	17	15	3	2
1.2	24	13	8	2
1.3	14	9	5	2
1.4	10	7	3	1
1.5	8	8	1	1
1.6	7	6	1	1
1.7	2	2	0	0
1.8	1	1	1	1
1.9	1	1	0	0
2.0	2	2	2	2
2.1	1	1	0	0
	467	68	149	13

Table 3-2: Cook 1, EOC 13, Comparison of PIs Found at TSPs, Confirmed by RPC, and Indications Repaired

	Steam Generator 11				Steam Generator 12				Steam Generator 13				Steam Generator 14				All Steam Generators			
Volts	No. of Bobbin Indications	No. of Indications Examined	No. of Indications Confirmed	No. of Indications Repaired	No. of Bobbin Indications	No. of Indications Examined	No. of Indications Confirmed	No. of Indications Repaired	No. of Bobbin Indications	No. of Indications Examined	No. of Indications Confirmed	No of Indications Repaired	No. of Bobbin Indications	No. of Indications Examined	No of Indications Confirmed	No. of Indications Repaired	No. of Bobbin Indications	No of Indications Examined	No of Indications Confirmed	No of Indications Repaired
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.2	2	0	0	0	3	0	0	0	1	0	0	0	2	0	0	0	8	0	0	0
0.3	4	0	0	0	3	0	0	0	5	0	0	1	8	0	0	1	20	0	0	2
0.4	22	0	0	1	12	0	0	1	11	0	0	0	23	0	0	1	68	0	0	3
0.5	24	0	0	1	21	0	0	1	13	0	0	0	19	1	0	2	77	1	0	4
0.6	28	0	0	2	14	0	0	0	13	0	0	0	27	0	0	0	82	0	0	2
0.7	23	0	0	1	11	0	0	0	7	0	0	0	27	0	0	0	68	0	0	1
0.8	20	1	0	0	13	0	0	0	13	0	0	1	17	2	0	0	63	3	0	1
0.9	16	0	0	2	9	0	0	0	7	0	0	0	15	13	1	2	47	13	1	4
1.0	7	0	0	1	9	0	0	0	5	0	0	0	17	17	5	1	38	17	5	2
1.1	6	6	2	0	1	1	0	1	2	2	1	0	8	8	0	1	17	17	3	2
1.2	2	2	1	0	3	3	2	0	5	5	3	0	3	3	2	0	13	13	8	0
1.3	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	2	2	1	0
1.4	0	0	0	0	1	1	0	0	1	1	1	0	3	3	1	0	5	5	2	0
1.5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
1.6	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	0	3	3	3	1
1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.8	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0	2	2	1	0
Total	156	11	4	9	103	8	4	3	84	9	5	2	171	49	11	8	514	77	24	22
Total > 1V	10	10	4	1	8	8	4	1	9	9	5	0	16	16	5	1	43	43	18	3

Table 3-3. SUMMARY OF LARGEST EOC-13 BOBBIN VOLTAGES						
S/G	Tube	TSP	EOC-13		BOC-13 Bobbin Volts	New Ind.
			Bobbin Volts	RPC Volts		
12	R11C70	2	1.77	NDD	1.50	No(1)
12	R11C55	2	1.72	0.20	1.68	No(2)
12	R8C24	2	1.54	0.63	1.58	No(2)
11	R6C83	1	1.53	0.61	1.28	Yes
14	R11C22	1	1.52	0.79	1.42	No(1)
13	R15C64	1	1.50	NDD	1.37	Yes
12	R11C56	2	1.40	NDD	1.33	No(1)
14	R11C15	1	1.38	0.33	1.21	No(2)
13	R31C72	1	1.35	0.27	1.39	No(2)
14	R5C30	2	1.32	NDD	1.16	No(1)
14	R29C44	1	1.32	NDD	1.26	No(1)
14	R21C58	1	1.27	0.22	1.16	No(1)
11	R21C12	1	1.27	NDD	1.21	Yes
12	R8C19	1	1.20	0.53	0.96	Yes
13	R6C58	1	1.19	0.68	1.33	No(2)
12	R11C68	1	1.18	NDD	0.82	Yes

Notes: 1. RPC NDD at last inspection
2. Field bobbin volts < 1.0 at last inspection

Figure 3-1a D. C. Cook-1: EOC-12 Bobbin Voltage Distribution for All SGs and RPC Confirmed Indications

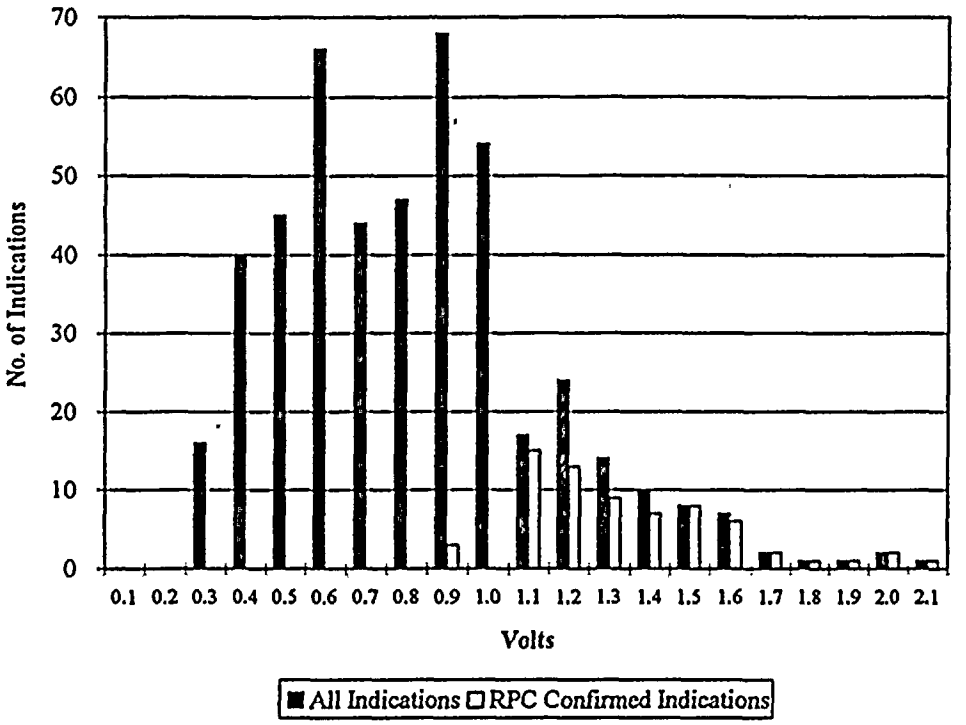


Figure 3-1b D. C. Cook-1: EOC-12 SG-14 Bobbin Voltage Distribution and RPC Confirmed Indications

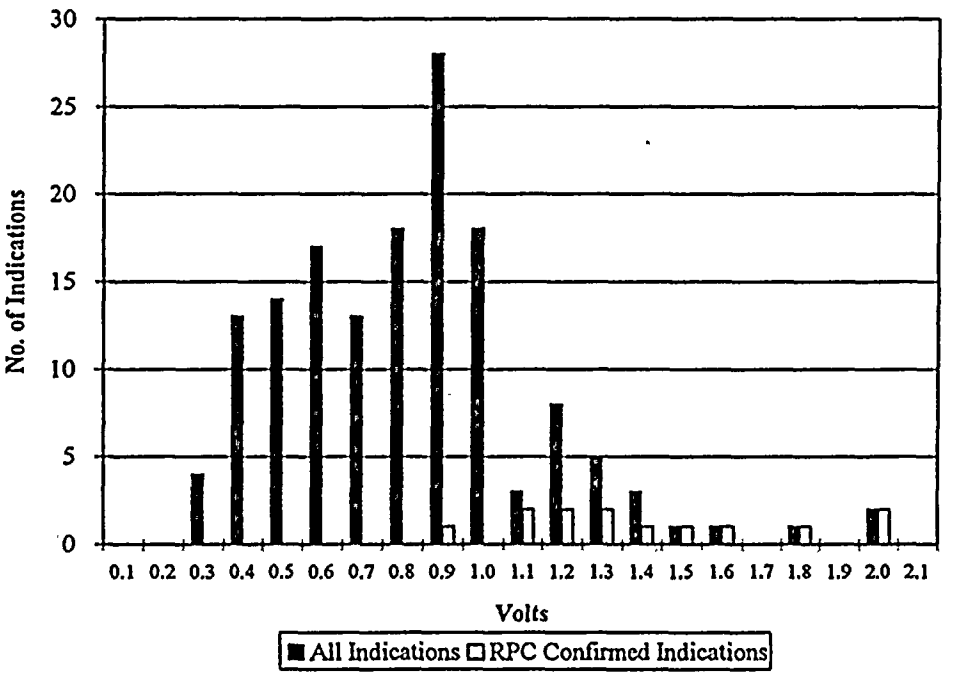


Figure 3-2. D. C. Cook-1: EOC-13, All S/Gs Bobbin Voltage Distributions

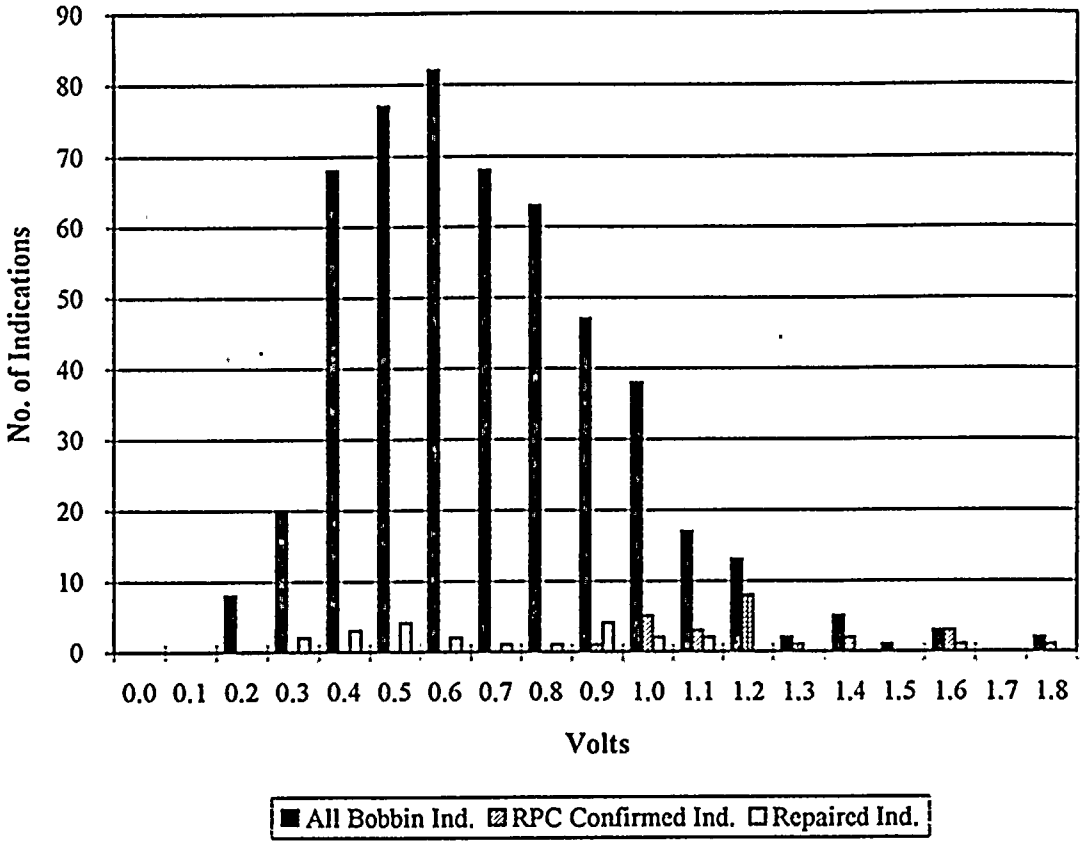


Figure 3-3a. D.C. Cook-1: EOC-13 SG 11 Bobbin Voltage Distributions

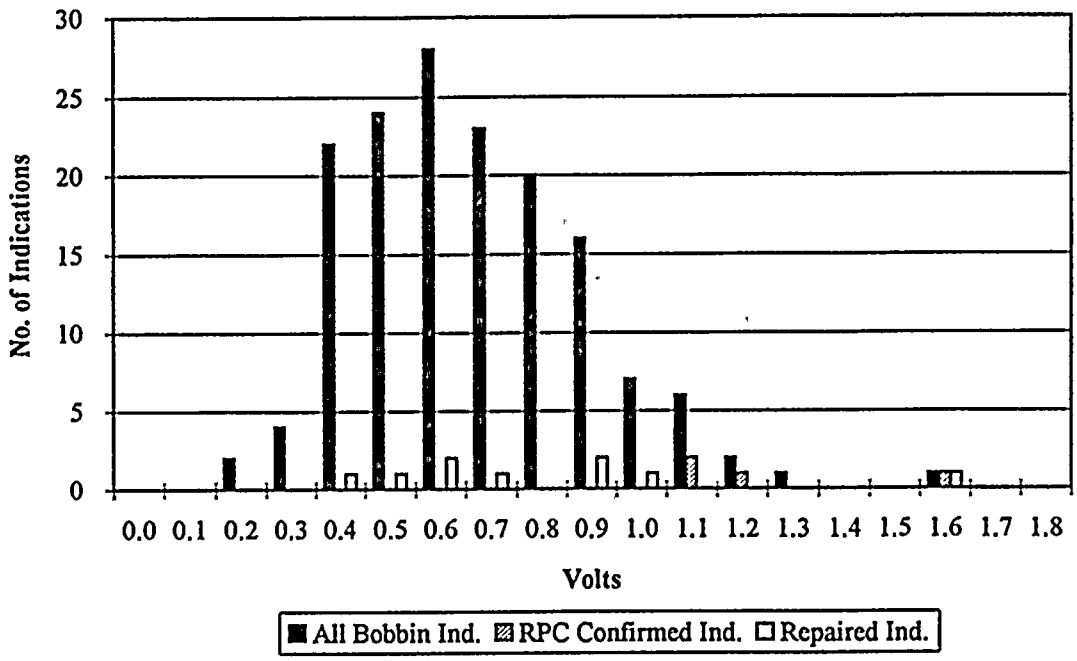
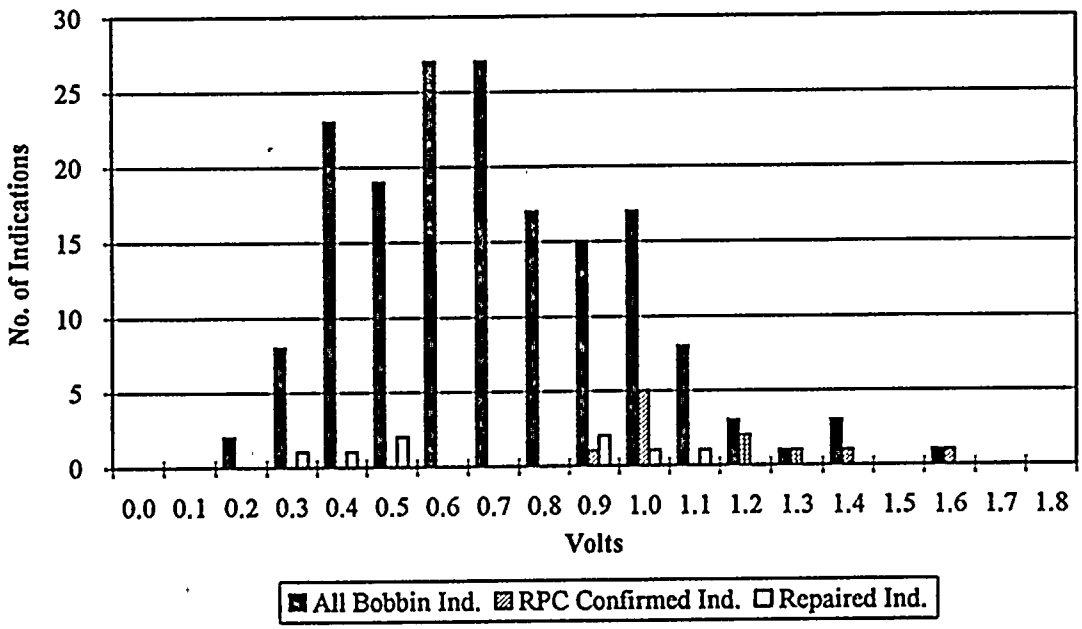


Figure 3-3b. D.C. Cook-1: EOC-13, SG 14 Bobbin Voltage Distributions



4.0 BOBBIN VOLTAGE INDICATIONS LEFT IN SERVICE

4.1 BOC-13 Indications Left in Service

The indications left in service at BOC-13 are used to project the EOC-13 voltage distribution for comparison with the actual distributions found at the EOC-13 inspection, as described in Section 3.2. The BOC-13 distributions are given for S/G-14, which was the limiting S/G with regard to the number and size of indications left in service for potential leakage considerations in Cycle 13. Two representations of the BOC-13 distributions are utilized in this report and are presented in this section.

The D. C. Cook-1 NRC SER requires that the indications found in the inspection be divided by a probability of detection (POD) of 0.6 and then reduced by the indications repaired to define the BOC distribution. Bobbin indications found to be NDD by RPC inspection are conservatively included as indications left in service. The NRC-required distribution with a POD of 0.6 applied is shown in Table 4-1 and in Figure 4-1. A second distribution is also included in Table 4-1 and Figure 4-1, which is the same as the NRC-required distribution except that there is no adjustment for POD. That is, the second distribution includes all detected bobbin indications not repaired independent of RPC confirmation. The largest RPC NDD indication left in service is 1.4 volts, however, the POD adjustment results in 1.3 indications at 2.0 volts left in service. Both distributions include RPC NDD indications left in service.

Since the POD adjustment is applied before the distribution is reduced for repaired tubes, the POD adjusted distribution shows more indications than is obtained by dividing all bobbin indications left in service by 0.6. For example, the adjusted distribution includes 1.3 indications at 2.0 volt which is obtained by dividing the two indications (both RPC confirmed and repaired) by 0.6 to obtain 3.3 indications which is then reduced by 2.0, since these indications were repaired. The effect of this conservative methodology is equivalent to assuming that one and one-third 2.0 volt indications were missed in the inspection even though the largest indications were found and repaired.

As required by the Cook-1 SER, the EOC-12 repaired indications for SG-14 are provided in tabular form in Table 4-1 (shown under BOC-13 column as Repaired Indications) and are also shown in Figure 4-2. Also required by the SER is the BOC-13 voltage distribution of indications that were "confirmed by RPC to be crack-like or not RPC inspected"; these are provided in Table 4-1 and Figure 4-3. The Figure 4-3 distribution is the same as the Figure 4-1 distribution of all BOC-13 bobbin indications, but excludes fifteen indications which were found to be RPC NDD. The RPC confirmed plus not RPC inspected distribution, although not utilized in the analysis, identifies some of the conservatism of including all RPC NDD indications in the BOC distribution.

4.2 BOC-14 Indications Left in Service

Bobbin voltage distributions for BOC-14 were developed in the same manner and for the comparable two distributions as described above for BOC-13. The reference distributions include all bobbin signals independent of RPC confirmation that were left in service. S/G 14 is the limiting S/G for Cycle 14 leakage considerations, which was determined by performing leakage calculations for the actual EOC-13 voltage distributions. S/G 14 had the higher EOC-13 leak rate of all SGs, and the same result would be expected at EOC-14.

The BOC-14 bobbin voltage distributions for SG-14 are given in Table 4-1 and shown in Figure 4-4. It is seen that the POD = 0.6 adjusted distribution includes additional tubes in service that are not present in the unadjusted data. The largest bobbin indication left in service at BOC-14 was in the 1.6 volt bin (between 1.51 and 1.6 volts). In this case, the largest BOC-14 indication left in service is the same with and without the POD adjustment since none of these indications were repaired at this outage. The distributions of Figure 4-4 are applied in Section 7 to obtain the projected EOC-14 voltage distributions. Figures 4-5 provides the requested BOC-14 distribution of RPC confirmed plus not RPC inspected indications. This distribution is provided as required by the SER and again identifies some of the conservatism of including all RPC NDD indications in the BOC distribution.

Table 4-1: Distribution of Indications for SG-14 at BOC-13 and BOC-14

	BOC-13 [1]					BOC-14 [2]				
Volts	All Indications	Repaired Indications	All Bobbin BOC-13	RPC Confirmed Plus Not RPC Inspected	POD = 0.6 BOC-13 (as per NRC SER)	All Indications	Repaired Indications	All Bobbin BOC-14	RPC Confirmed Plus Not RPC Inspected	POD = 0.6 BOC-14 (as per NRC SER)
0.1	0	0	0	0	0.0	0	0	0	0	0.0
0.2	0	0	0	0	0.0	2	0	2	2	3.3
0.3	4	0	4	4	6.7	8	1	7	7	12.3
0.4	13	1	12	12	20.7	23	1	23	22	37.3
0.5	14	1	13	13	22.3	19	2	17	16	29.7
0.6	17	0	17	16	28.3	27	0	26	27	45.0
0.7	13	0	13	13	21.7	27	0	27	27	45.0
0.8	18	0	18	17	30.0	17	0	17	15	28.3
0.9	28	3	25	24	43.7	15	2	13	2	23.0
1.0	18	1	17	17	29.0	17	1	16	5	27.3
1.1	3	2	1	0	3.0	8	1	7	0	12.3
1.2	8	2	6	0	11.3	3	0	3	2	5.0
1.3	5	2	3	0	6.3	1	0	1	1	1.7
1.4	3	1	2	0	4.0	3	0	3	1	5.0
1.5	1	1	0	0	0.7	0	0	0	0	0.0
1.6	1	1	0	0	0.7	1	0	1	1	1.7
1.7	0	0	0	0	0.0	0	0	0	0	0.0
1.8	1	1	0	0	0.7	0	0	0	0	0.0
1.9	0	0	0	0	0.0	0	0	0	0	0.0
2.0	2	2	0	0	1.3	0	0	0	0	0.0
Totals	149	18	131	116	230.3	171	8	163	128	277.0

[1] Field voltages for DI's reported in 1992.

[2] '94 voltages of PI, PIN, and PCN reported in '94.

Figure 4-1
BOC-13 Distribution of All SG-14 Indications Returned to Service (POD=1.0) vs. NRC SER Distribution with POD=0.6

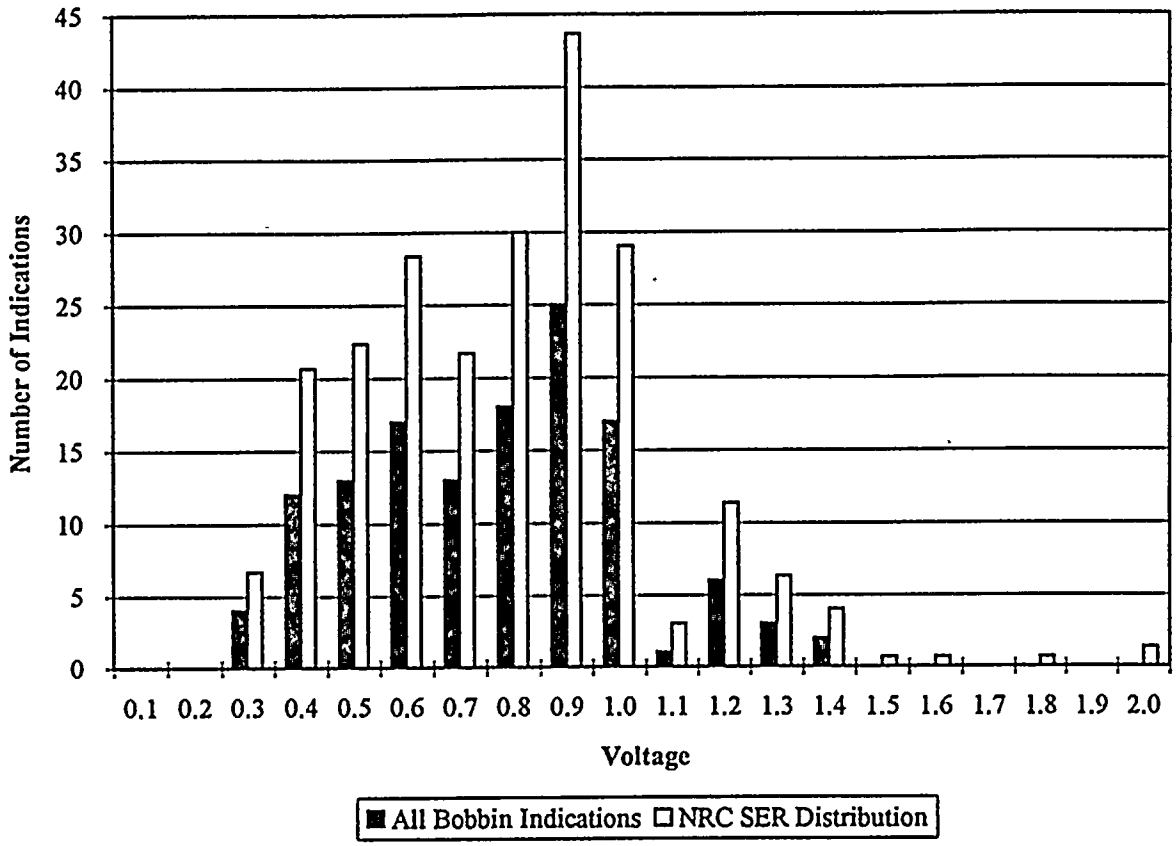


Figure 4-2. EOC-12 SG-14 Repaired Indications

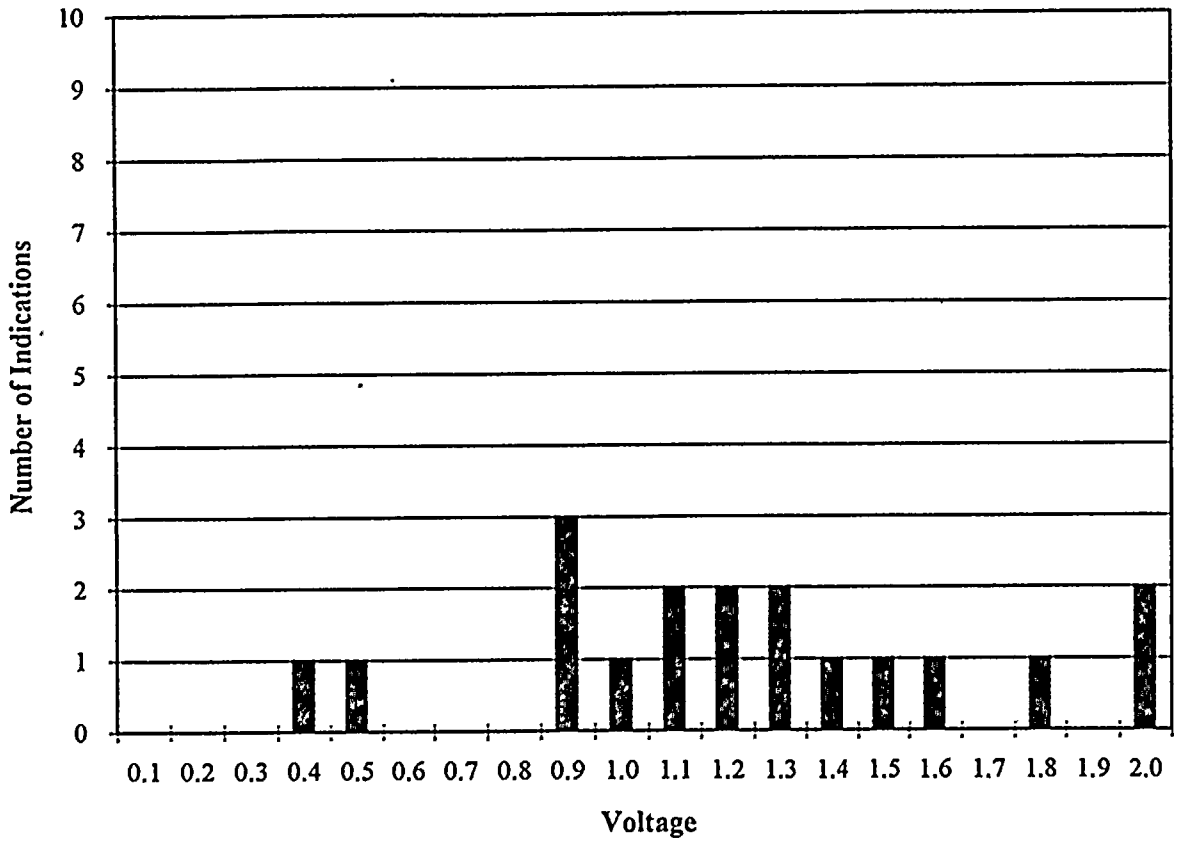


Figure 4-3. BOC-13 SG-14 Indications RPC Confirmed Plus Not RPC Inspected (POD=1.0)

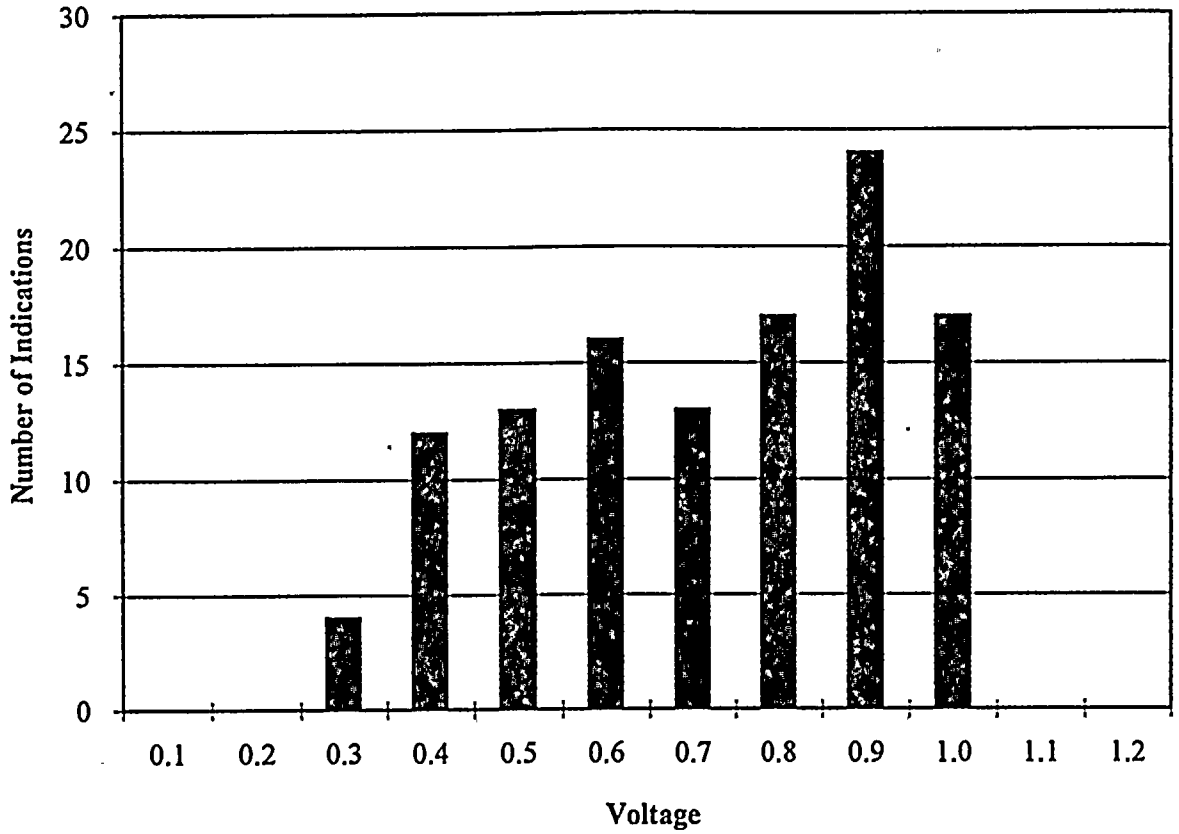


Figure 4-4
BOC-14 Distribution of All SG-14 Indications Returned to Service (POD=1.0) vs. NRC SER Distribution with POD=0.6

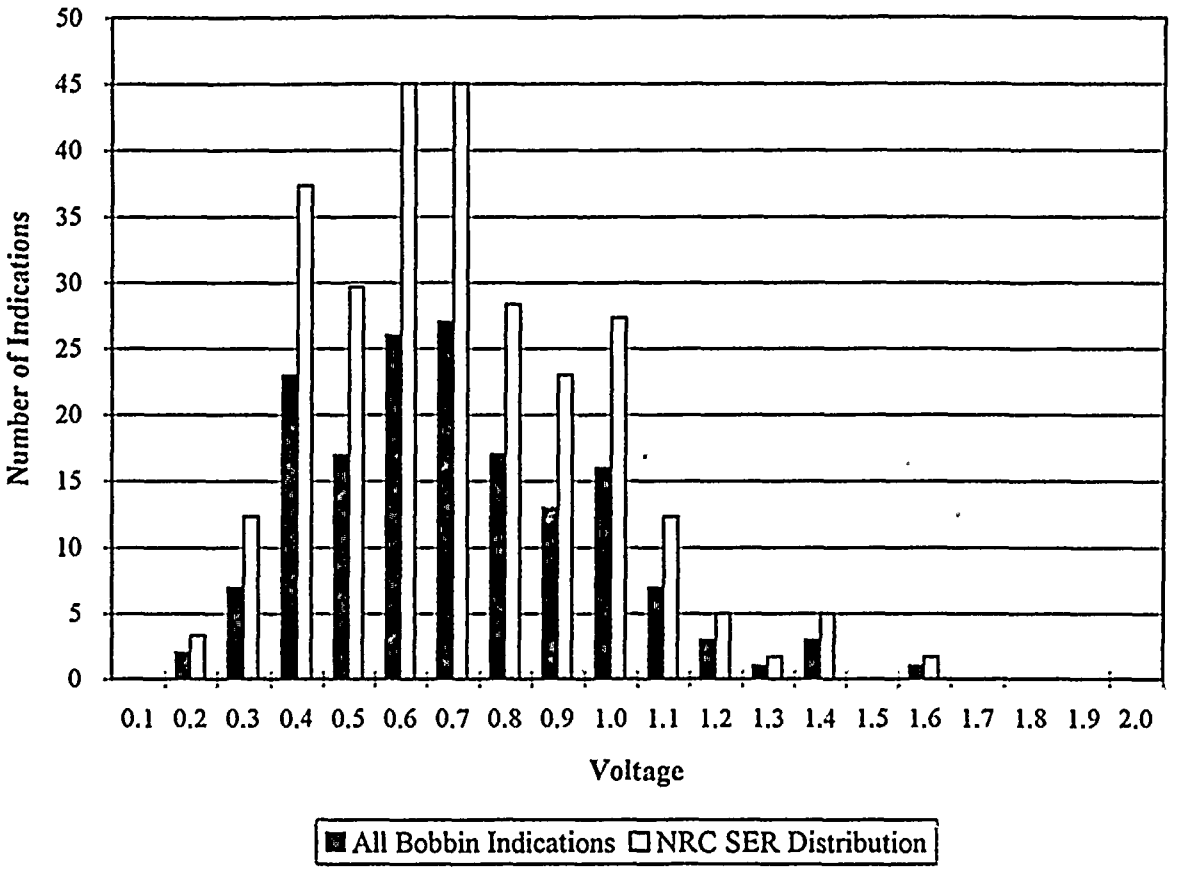
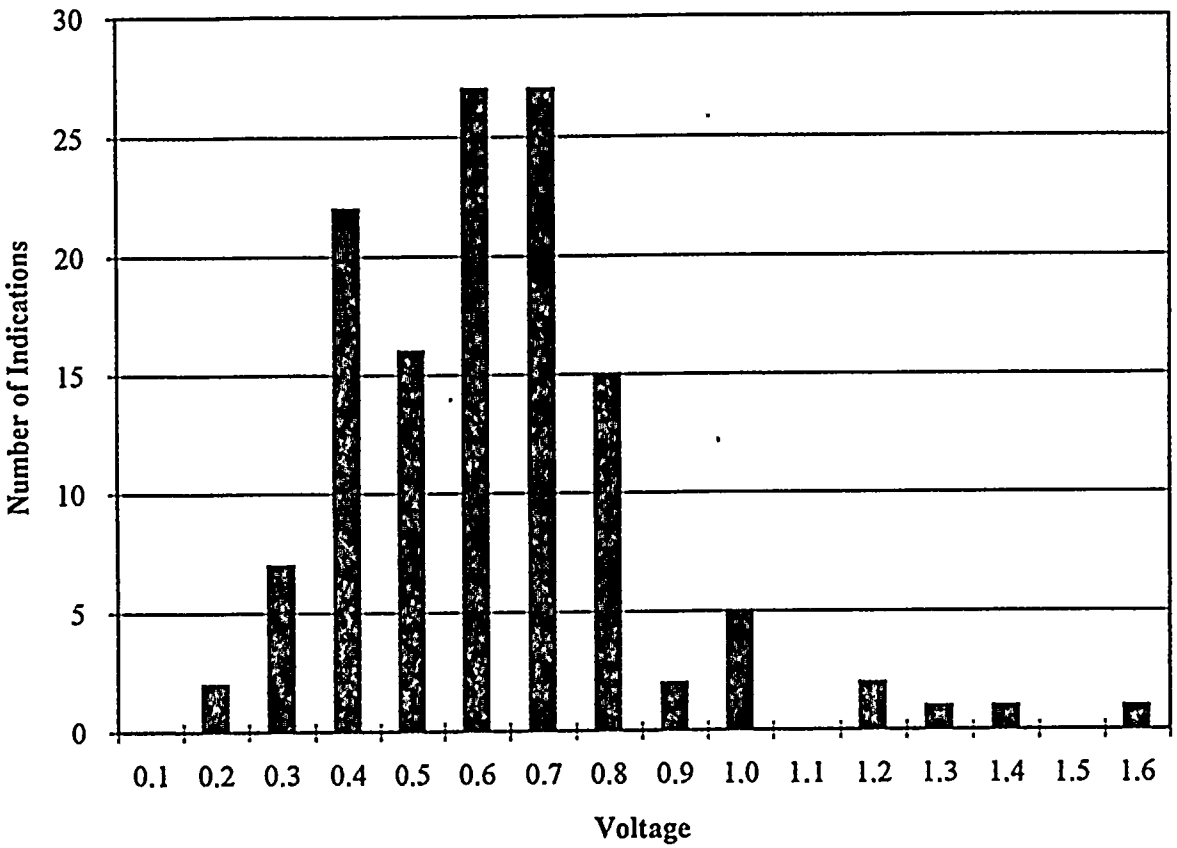


Figure 4-5. BOC-14 SG-14 Indications RPC Confirmed Plus Not RPC Inspected (POD=1.0)



5.0 VOLTAGE GROWTH RATES

5.1 Cycle 12 Voltage Growth Rates

Voltage growth rates for Cycle 12 were developed at EOC-12 by a single analyst. The use of a single analyst provides consistency to the analysis and enhances the accuracy of the growth data. The evaluation included calibration corrections for normalizing ASME standard voltages to the reference laboratory standard used in the APC database development.

These data were used to develop growth distributions. No cycle length adjustments were made to the Cycle 12 growth rates; the Cycle 12 operating period was 455 EFPD. Figure 5-1 shows the Cycle 12 voltage growth distribution. The largest growth value was 0.49 volts and found for only one indication. Only 4 indications had voltage growth values > 0.3 volt.

Table 5-1 summarizes the average growth rates for Cook-1 Cycles 12 and 13. Table 5-2a presents the cumulative growth distribution for Cycle 12. The Cycle 12 (1990 to 1992) average growth was 0.02 volt or 2.2% of the BOC-12 average of 1.00 volt. The average growth for BOC indications < 0.75 volt was 12% while the average growth for indications > 0.75 volts was only 1%. (Note: One indication was deleted from the 1992 growth study based on re-review; it had a growth value very near to the mean and therefore negligible effect on the overall growth distribution.)

5.2 Cycle 13 Voltage Growth Rates

The Cycle 13 voltage growth rates were developed utilizing the 1994 field analysis data and a single analyst to reevaluate the 1992 data for the same indications. Again, the use of a single analyst provides consistency to the analysis and enhances the accuracy of the growth data. Reference 4 Appendix A guidelines were used in the 1994 inspection including cross calibration of the field ASME standards to the reference laboratory standard. Growth rates were developed for all potential flaws (PI, PIN, PCN classifications). INR and UOA signals, which are not considered to be flaw indications, were also analyzed but not included in the growth rate analysis.

The Cycle 13 growth distribution is shown in Figure 5-2, and Table 5-2b presents the cumulative growth distribution for Cycle 13. The largest growth value is 0.4 volts which is lower than the value of 0.49 volts found for Cycle 12. Cycle 13 shows only 2 growth values > 0.3 volt, as compared to 4 for Cycle 12. The median bin for both Cycles 12 and 13 is 0.1 volts. The more conservative Cycle 12 growth distribution of Figure 5-1 is used to project BOC-14 indications left in service to EOC-14 conditions, as described in Section 7.

Table 5-3 shows the bobbin and RPC results for indications with a growth rate $\geq$ 0.20 volts. Also shown is whether the indication was a new indication reported in the 1994 inspection. Five of the 20 indications with the largest growth rates were confirmed by RPC, and five of the 20 indications were RPC NDD; the remaining were not RPC inspected. Seven of the indications were new indications in the 1994 inspection.

Table 5-1 summarizes the average voltage growth rates for Cycle 13 (1992 to 1994). The average growth rate is 0.01 volts or 1.4% for Cycle 13 which is slightly smaller than the 2.2% found for Cycle 12. The average BOC voltage for Cycle 13 was 0.64 volts, compared to 1.00 volts for Cycle 12.

Figure 5-3 and Table 5-1 illustrate the growth rates for SG 11 through 14. Although SG 14 has the greater number of indications, the average growth rate for this SG was essentially zero for Cycle 13. SG 12 growth rates at 4.2% were weighted by some of the larger growth values seen in Table 5-3, but averaged only 0.03 volts.

Figure 5-4 provides a comparison of the Cycle 12 and Cycle 13 growth distributions. Cycle 13 shows lower growth rates than that of Cycle 12 over most of the range, as well as at the maximum values. The decreasing growth rate trends for the Cook S/Gs indicate the effect of recent plant operations such as chemistry and cleaning efforts to control and reduce the growth of ODSCC at TSP intersections.

Table 5-1. Average Voltage Growth Per Cycle for Cook-1

Cycle	Number Indications	Average BOC Voltage	Average ΔV Growth/Cycle	Percent Growth
Cycle 12: '90-'92				
All Indications	201	1.00	0.02	2.2%
V_{BOC} < 0.75V	30	0.67	0.08	12%
V_{BOC} > 0.75V	171	1.07	0.01	1%
Cycle 13: '92-'94				
SG-11 All Indications V_{BOC} < 0.75V V_{BOC} > 0.75V	 156 115 41	 0.62 0.52 0.92	 0.01 0.00 0.02	0.8%
SG-12 All Indications V_{BOC} < 0.75V V_{BOC} > 0.75V	 103 73 30	 0.64 0.50 0.99	 0.03 0.01 0.08	4.2%
SG-13 All Indications V_{BOC} < 0.75V V_{BOC} > 0.75V	 84 54 30	 0.65 0.48 0.95	 0.02 0.01 0.03	2.5%
SG-14 All Indications V_{BOC} < 0.75V V_{BOC} > 0.75V	 171 114 57	 0.66 0.51 0.96	 ~0.00 0.02 ~0.00	~0.0%
All SGs All Indications V_{BOC} < 0.75V V_{BOC} > 0.75V	 514 356 158	 0.64 0.50 0.95	 0.01 ~0.00 0.03	1.4%

Table 5-2a
Cook-1 Cycle 12 Growth Distribution - All SGs

Voltage	No.	Cum. %	Cumulative
-0.50	0	0.0%	0
-0.40	1	0.5%	1
-0.30	1	1.0%	2
-0.20	9	5.5%	11
-0.10	16	13.4%	27
0.00	57	41.8%	84
0.10	71	77.1%	155
0.20	34	94.0%	189
0.30	8	98.0%	197
0.40	1	98.5%	198
0.50	3	100.0%	201

Note: Negative growths are not included in applications for projecting EOC distributions.

Table 5-2b
Cook-1 Cycle 13 Growth Distribution - All SGs

Voltage	No.	Cum. %	Cumulative
-0.30	0	0.0%	0
-0.20	16	3.1%	16
-0.10	50	12.8%	66
0.00	180	47.9%	246
0.10	200	86.8%	446
0.20	52	96.9%	498
0.30	14	99.6%	512
0.40	2	100.0%	514

Note: Negative growths are not included in applications for projecting EOC distributions.

Table 5-3. Summary of Largest Bobbin Voltage Growth Rates for Cook-1 Cycle 13

SG	Row	Col	TSP	EOC13		BOC13 Bobbin Volts	Voltage Growth (Volts)	New Indication
				Bobbin Volts	RPC Volts			
12	13	66	2H	0.96	N.I.	0.56	0.40	Yes
12	11	68	1H	1.18	NDD	0.82	0.36	Yes
13	39	23	2H	0.97	N.I.	0.67	0.30	No
11	40	40	2H	1.03	NDD	0.76	0.27	No
12	11	70	2H	1.77	NDD	1.50	0.27	No
11	6	83	1H	1.53	0.61 (1)	1.28	0.25	Yes
12	8	3	2H	1.13	0.57	0.88	0.25	No
12	8	19	1H	1.20	0.53	0.96	0.24	Yes
14	38	41	1H	0.87	NDD	0.63	0.24	No
11	2	61	1H	0.73	N.I.	0.50	0.23	Yes
11	25	66	1H	0.94	N.I.	0.72	0.22	No
12	4	18	1H	0.93	N.I.	0.71	0.22	No
12	4	6	1H	0.62	N.I.	0.41	0.21	No
14	8	19	3H	1.14	0.26	0.93	0.21	Yes
14	11	22	3H	0.99	0.36	0.78	0.21	No
14	5	30	3H	0.85	NDD	0.64	0.21	No
11	29	54	1H	0.55	N.I.	0.35	0.20	Yes
12	8	13	1H	0.79	N.I.	0.59	0.20	No
13	11	53	3H	0.86	N.I.	0.66	0.20	No
13	10	83	2H	0.89	N.I.	0.69	0.20	No

N.I. = Not RPC Inspected.

(1) Tube repaired.

Figure 5-1 Cook-1 Cycle 12 ODSCC Growth Distribution

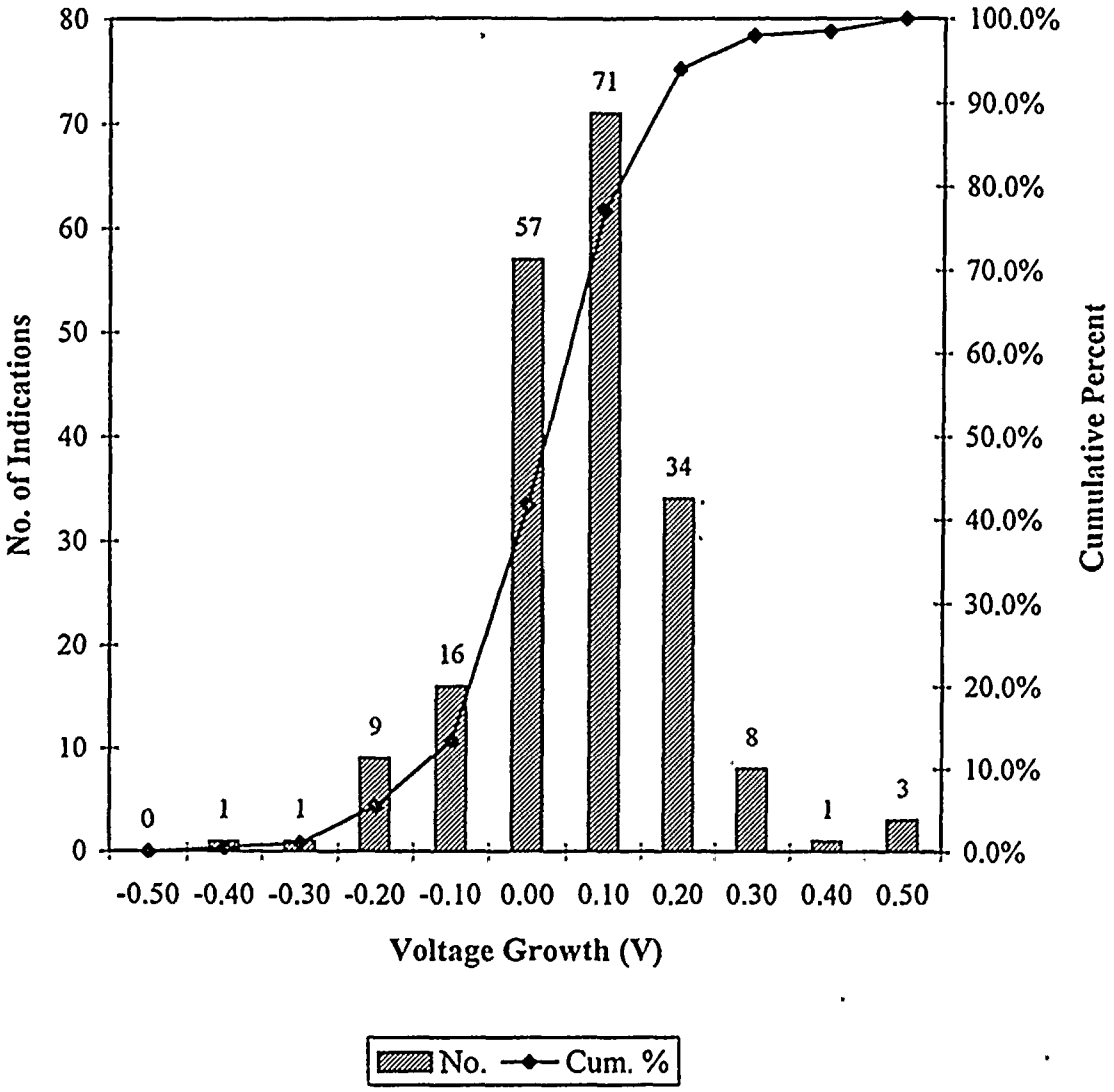


Figure 5-2 Cook-1 Cycle 13 Growth Distribution

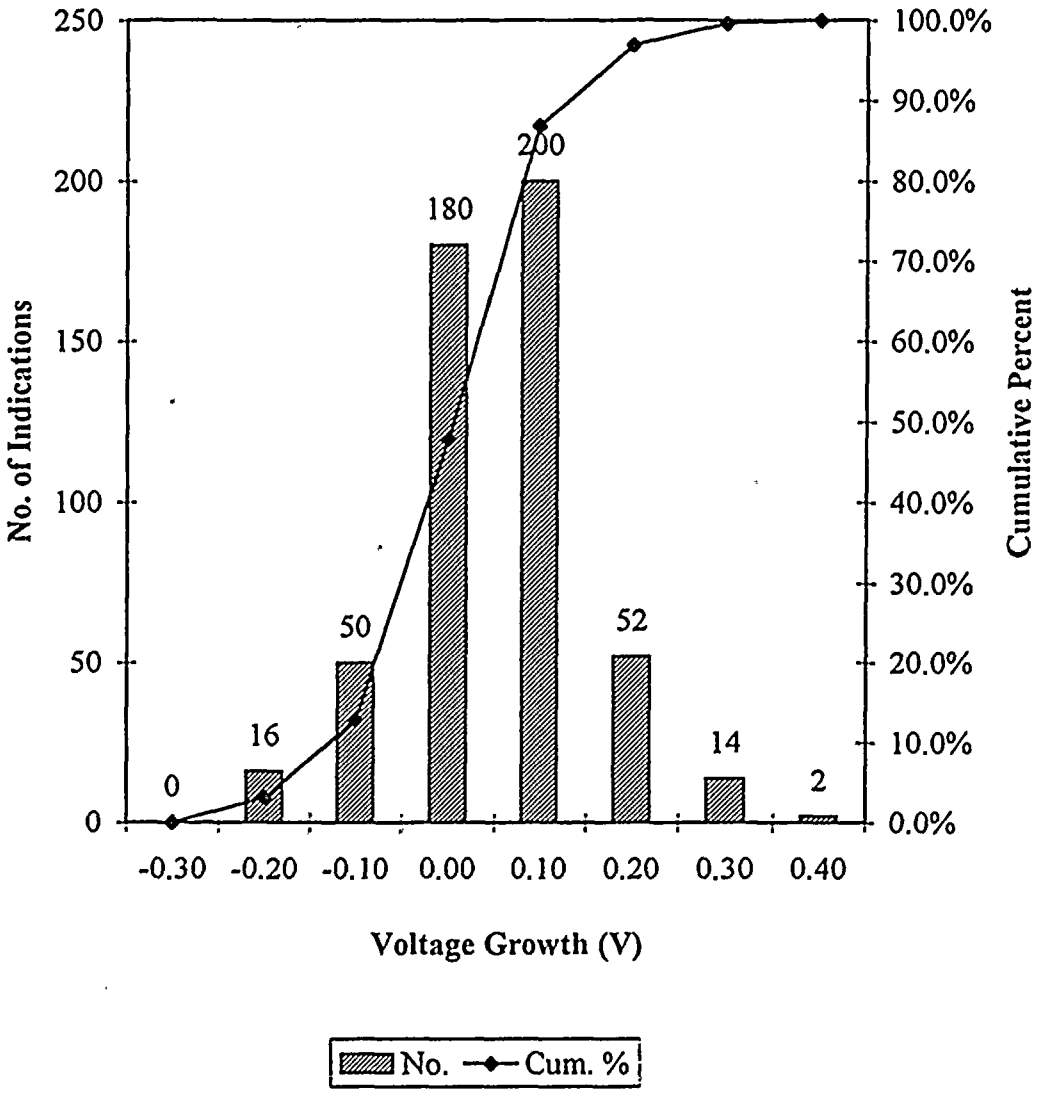


Figure 5-3 Cook-1 Cycle 13 PI Growth Rates by SG (514 PIs)

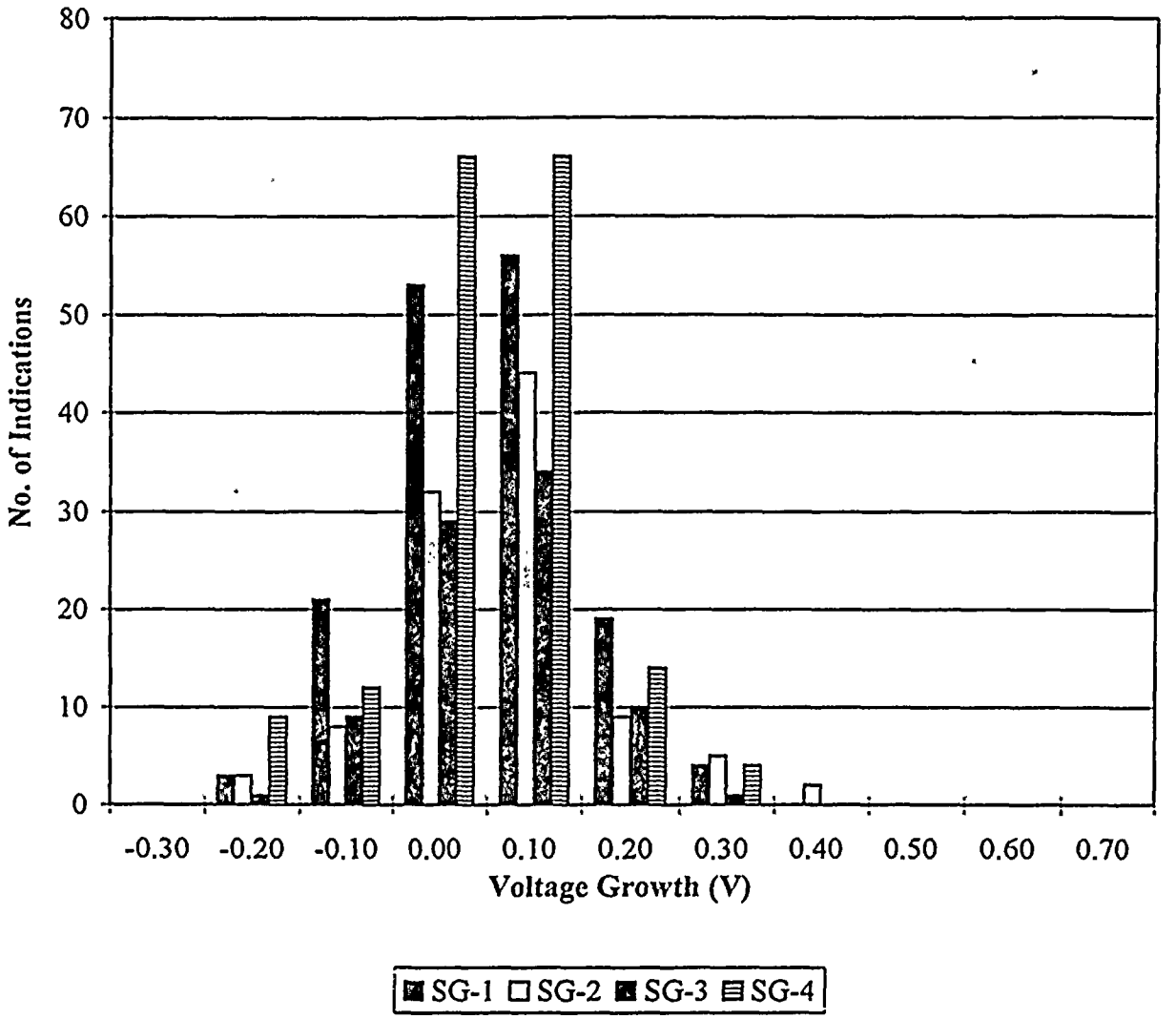
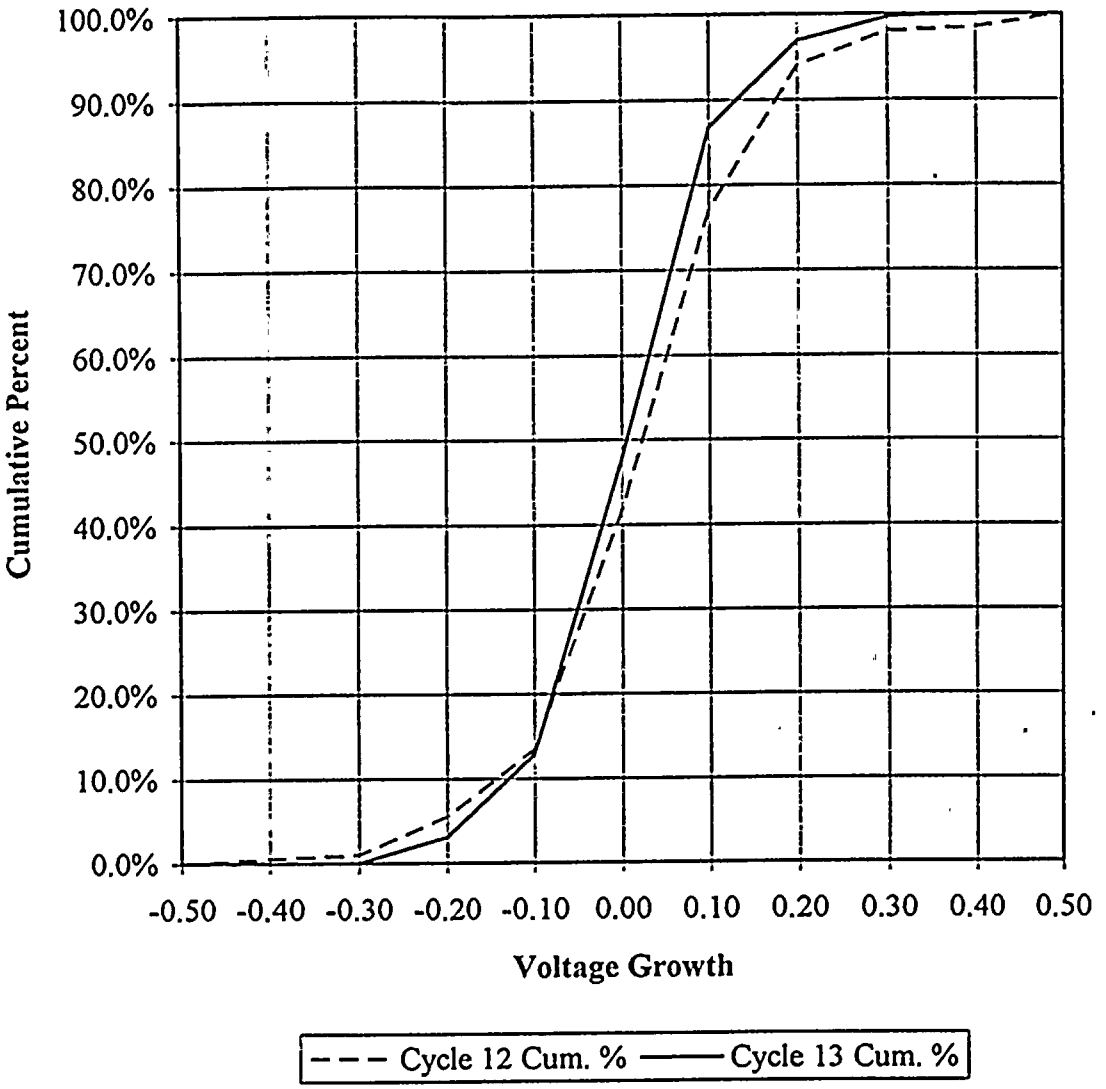


Figure 5-4 Comparison of Cook-1 Cycle 12 and Cycle 13 Growth Rates



6.0 NDE UNCERTAINTIES

NDE uncertainties for voltage measurements were developed for Cook units in WCAP-13187 (Ref. 4). The NDE uncertainty developed in the WCAP was updated in Reference 7, EPRI Report TR-100407, Revision 1 (Draft of August 1993). While the WCAP and EPRI reports differ slightly in the components of the net NDE uncertainty and in the development, the net NDE uncertainty is not significantly different (12% standard deviation in the WCAP versus 12.5% in the EPRI report) and the EPRI NDE uncertainty is applied for both Cycles 13 and 14 for Cook-1.

The NDE uncertainty is principally due to probe wear, which has a standard deviation of approximately 7% about a mean of zero, and to analyst variability which has a standard deviation of 10.3%. These distributions are applied as normal distributions and combined (in a square root sum-of-the-squares method) to obtain a net NDE uncertainty of 12.5% for one standard deviation. The upper bound on the probe wear uncertainty is limited to 15% since worn bobbin probes at Cook-1 are replaced. Probe replacement occurs when the worn probe voltage measurement from the probe wear standard differs by more than 15% from the probe wear standard voltage determined from the probe when new. The eddy current analysis guidelines require lead analyst resolution of bobbin voltages (with one or more reported above 1.0 volt) differing between analysts by more than 20%, which therefore limits the upper bound on analyst variability uncertainty to 20%. However, as of the February 8, 1994, NRC/Industry meeting, the NRC had not accepted the 20% cutoff on the analyst variability uncertainty. Pending further resolution of this issue with the NRC, the analyst uncertainty is applied without a cutoff for the EOC voltage projections performed in this report. In this report, EOC voltage projections are determined using a probe wear distribution of 7% with a cutoff at 15% along with an analyst variability of 10.3% with no cutoff.

7.0 PROJECTED EOC VOLTAGE DISTRIBUTIONS

7.1 Projected EOC-13 Voltage Distributions

Consistent with the Reference 4 WCAP methodology, Monte Carlo analyses are applied to develop projected EOC distributions from the BOC distributions. The BOC voltages are increased by allowances for NDE uncertainties (from Section 6) and voltage growth (from Section 5) to obtain the EOC values. In the Monte Carlo analyses, each voltage bin of the BOC voltage distributions (Figure 4-1 for example) is increased by a random sample of the NDE uncertainty and growth distributions to obtain an EOC voltage sample. Each sample is weighted by the number of indications in the bin. The sampling process is repeated for each BOC voltage bin and then repeated for a large number of samples across the BOC distribution. In the present analyses, 100,000 samples for each bin of the BOC distribution were applied. The EOC projections were performed for S/G 14 which is the limiting S/G for both Cycles 13 and 14.

The projected EOC-13 bobbin voltage distributions are shown in Figures 7-1a and 7-1b and Table 7-1 for the two categories of BOC distributions discussed in Section 4.1 and shown in Figure 4-1. For the POD = 0.6 adjusted distribution, the maximum projected EOC-13 voltage is 2.4 volts. Since the Monte Carlo analysis yields a cumulative probability distribution of EOC voltages, a method must be defined to obtain a discrete maximum EOC voltage value. Previously, the tail of the distribution was integrated to obtain a voltage value corresponding to one remaining indication. To provide additional conservatism in the overall analysis and enhance the estimation of the maximum voltage, and based upon informal discussions with the NRC, the above approach has been modified in this report. In this report, the tail of the Monte Carlo distribution is integrated over the largest 2/3 of an indication to define a discrete value with an occurrence of 0.7 indication, and the tail over the largest 1/3 of an indication is integrated to define a discrete value with an occurrence of 0.3 indication. Thus, the last indication is distributed over two larger voltage values than would have been previously used. For N indications in the distribution, this is equivalent to evaluating the cumulative probability distribution of voltages at probabilities of (N-0.67)/N and (N-0.33)/N versus (N-1)/N.

The largest voltages for all distributions developed by Monte Carlo in this report have been obtained with the updated definition of the maximum EOC discrete voltage. The largest EOC-13 voltage for the distribution of all indications without POD adjustment (POD = 1.0) is 1.9 volts. In the 1992 SLB leak rate evaluation for EOC-13 using only bobbin indications < 1.0 volt left in service, a maximum EOC-13 voltage of 1.4 volts was reported for all indications without POD adjustment. The difference between 1.4 volts and the 1.9 volts of this report is due to the current analyses including RPC NDD indications in the analysis and the method (0.7 and 0.3 of an indication in this report versus one indication in the prior analysis) used to define the reported maximum voltage.

7.2 Comparison of Projected and Actual EOC-13 Distributions

In comparing projected and actual distributions, it is necessary to consider the purpose of the projections in order to define the appropriate actual distributions. The Cook-1 EOC inspection results include many RPC NDD indications. The projected EOC voltage distributions for IPC applications are applied to project SLB leakage and tube burst probability. As discussed in Section 3.3 in developing the EOC-13 distribution for comparisons with projections, RPC NDD indications have a negligible likelihood of potential SLB leakage over the prior cycle and should be ignored in

comparing IPC projections with the actual distributions. Thus the comparisons of IPC projections with actual distributions are made for EOC-13 RPC confirmed indications summed with indications not RPC inspected since it cannot be stated with confidence that the latter indications would not have leaked over the prior cycle. The appropriate S/G 14 EOC-13 actual distribution for RPC confirmed and untested (not RPC inspected) indications for this comparison are given in Figures 7-1a and 7-1b and Table 7-1. There are 133 indications in this EOC distribution. For comparison, projected voltage distributions are also provided with the distribution of all 171 indications for SG-14 at EOC-13 including RPC NDD indications in Figures 7-2a and 7-2b.

Figures 7-1a and 7-1b show the comparison of projected and actual EOC-13 voltage distributions (excluding RPC NDDs as discussed above). Figures 7-1a shows the NRC model (Figure 4-1 for BOC-13 distributions) which includes a POD = 0.6 applied to the EOC-12 inspection results. It is seen that the NRC model leads to significant conservatism both in the number of indications (230 versus actual 133) with leakage potential and in the largest EOC voltages. The NRC model leads to projected voltages as high as 2.4 volts and overestimates the number of indications in all voltage bins except < 0.7 volt. Figure 7-1b shows the comparison for the projection of all indications without a POD adjustment. This projection is also conservative above 0.7 volts although less conservative than the NRC model. The projection based on Monte Carlo analyses has distributed the indications more continuously over the voltage range, as would be expected, in comparison to the discrete actual indications and represents a conservative number of indications above 1.0 volts. This results from RPC NDD indications included in the BOC distribution exceeding the new RPC confirmed indications.

A comparison of projected distributions with the EOC-13 distribution for all indications independent of RPC confirmation is shown in Figure 7-2a and 7-2b. As noted above, this actual distribution includes RPC NDD indications which would not be expected to leak at EOC-13. For this case, the NRC model (POD = 0.6) still significantly exceeds the distribution. The results for a POD = 1.0 show enhanced, conservative agreement with the actual distribution above 0.7 volt and underestimates the number of small indications less than 0.7 volt. However, attempting to project the distribution for all indications would lead be overconservative if applied to SLB leakage analyses.

7.3 Projected EOC-14 Voltage Distributions

The BOC-14 voltage distributions are described in Section 4.2 and Figure 4-4. Monte Carlo methods are applied conservatively using the Cycle 12 voltage growth distribution of Figure 5-1 to obtain the projected EOC-14 distributions. As above for Cycle 13, projections to EOC-14 have been made for two distributions including the NRC model with a POD = 0.6 and all bobbin indications left in service including RPC NDD.

Figure 7-3 shows the projections with and without the POD = 0.6 adjustment. The conservatism of the NRC model, as reflected in the BOC distribution of Figure 4-2, is seen in the EOC-14 distributions. The NRC model projects to an EOC maximum voltage of about 2.0 volts compared to 1.9 volts for all indications left in service. The close agreement between the two projections for the maximum voltage results from the fact that no tubes were plugged for indications at the TSP intersections. Thus the NRC model, while having a larger number of indications left in service, does not result in higher voltage indications left in service than that for all bobbin indications left in service.

Table 7-1. D.C. Cook-1: Actual and Projected EOC-13 Distributions

Volts	Actual EOC-13 Distribution		Projected EOC-13 Distributions	
	All Ind.	RPC Conf./Untested	All Ind. POD=0.6	All Ind. POD=1.0
0.2	2	2	0	0
0.3	8	8	3	2
0.4	23	23	11	6
0.5	19	18	20	12
0.6	27	27	23	14
0.7	27	27	26	15
0.8	17	15	28	17
0.9	15	3	31	18
1.0	17	5	29	17
1.1	8	0	21	12
1.2	3	2	14	7
1.3	1	1	9	5
1.4	3	1	5	3
1.5	0	0	4	1
1.6	1	1	2	1
1.7	0	0	2	0
1.8	0	0	0	0.7
1.9	0	0	1	0.3
2.0	0	0	0	0
2.1	0	0	0	0
2.2	0	0	0.7	0
2.3	0	0	0	0
2.4	0	0	0.3	0
Totals	171	133	230	131

Table 7-2. D.C. Cook-1: Projected EOC-14 Distributions

Volts	All Indications POD=0.6	All Indications POD=1.0
0.2	1	1
0.3	6	3
0.4	20	12
0.5	33	19
0.6	36	21
0.7	40	24
0.8	37	22
0.9	30	18
1.0	25	14
1.1	18	11
1.2	13	7
1.3	7	5
1.4	5	2
1.5	2	2
1.6	2	1
1.7	1	0
1.8	1	0.7
1.9	0.7	0.3
2.0	0.3	0
Totals	278	163

Figure 7-1a. D.C. Cook-1: S/G 14 Comparison of Projected and Actual RPC Confirmed/Untested EOC-13 Voltage Distributions All Indications, POD=0.6

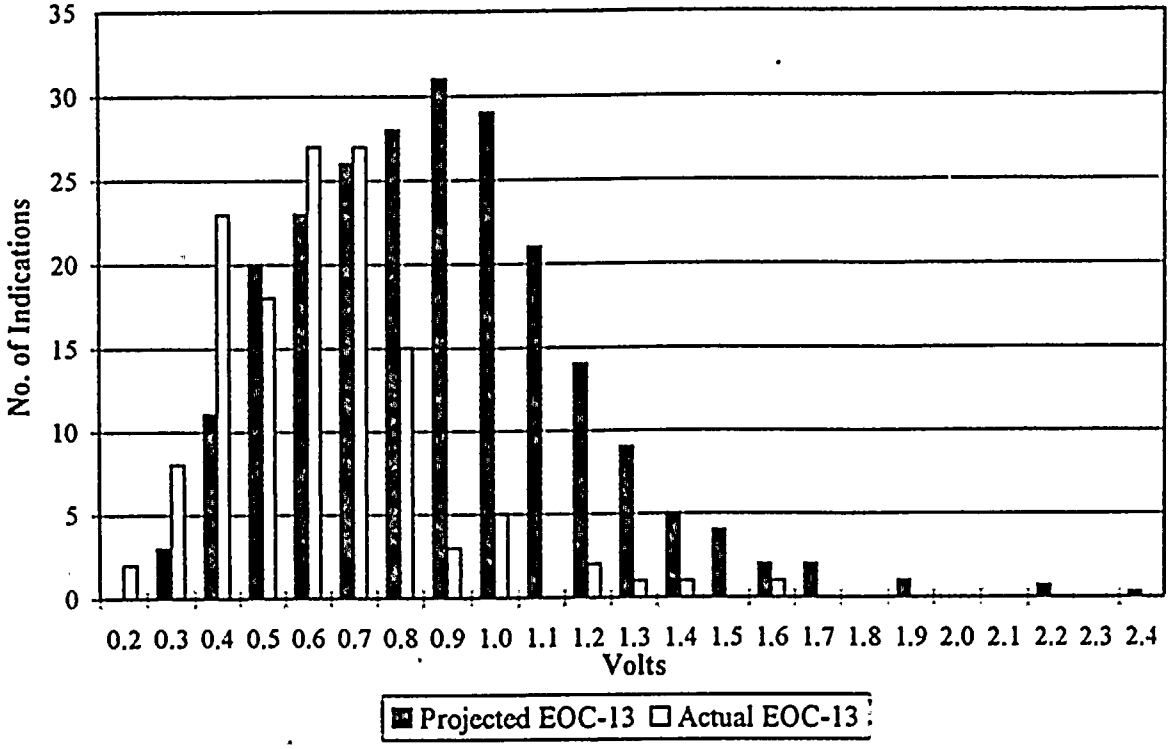


Figure 7-1b. D.C. Cook-1: S/G 14 Comparison of Projected and Actual RPC Confirmed/Untested EOC-13 Voltage Distributions All Indications, POD = 1.0

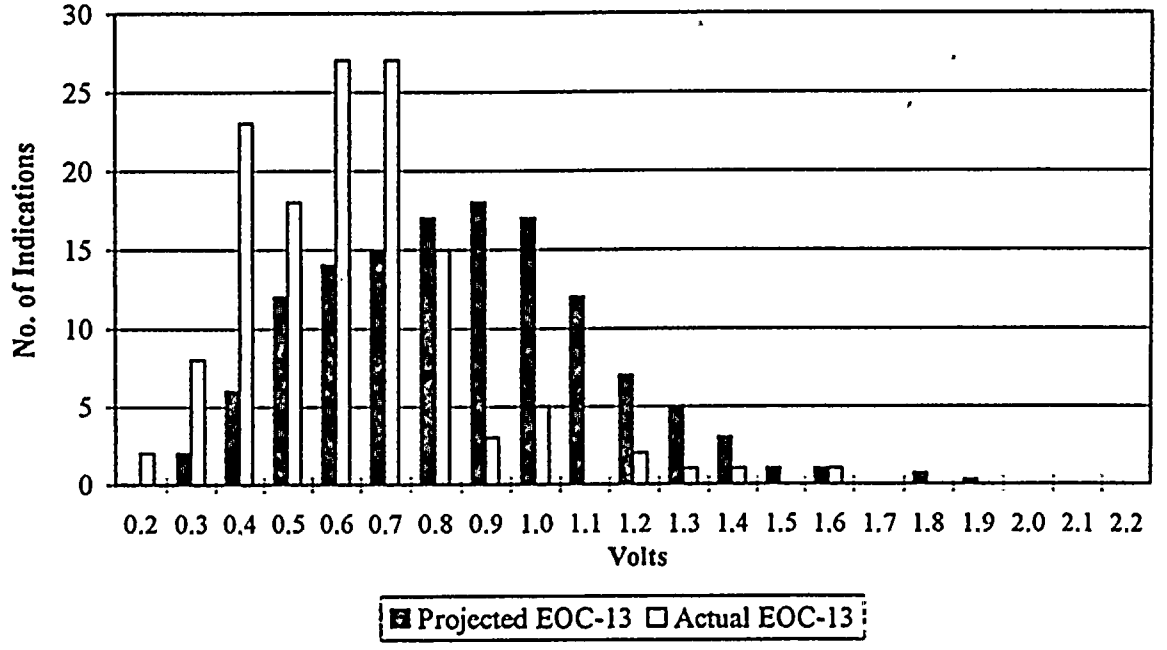


Figure 7-2a. D.C. Cook-1: S/G 14 Comparison of Projected and Actual All Indication EOC-13 Voltage Distributions
All Indications, POD=0.6

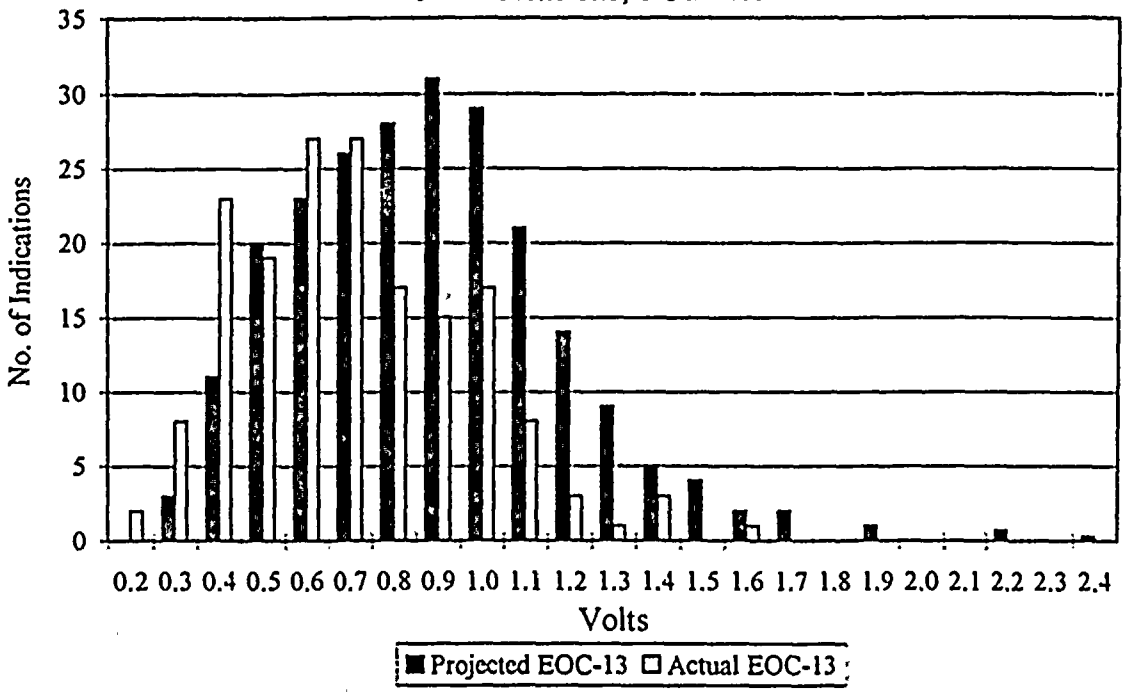


Figure 7-2b. D.C. Cook-1: S/G 14 Comparison of Projected and Actual All Indication EOC-13 Voltage Distributions
All Indications, POD=1.0

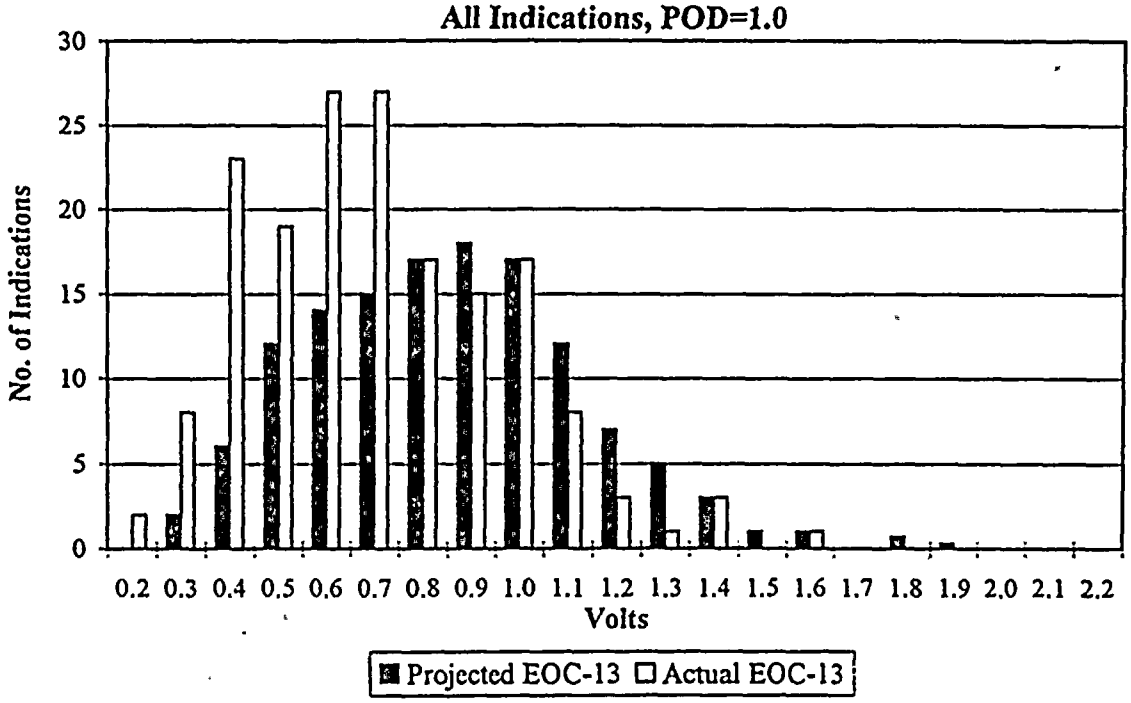
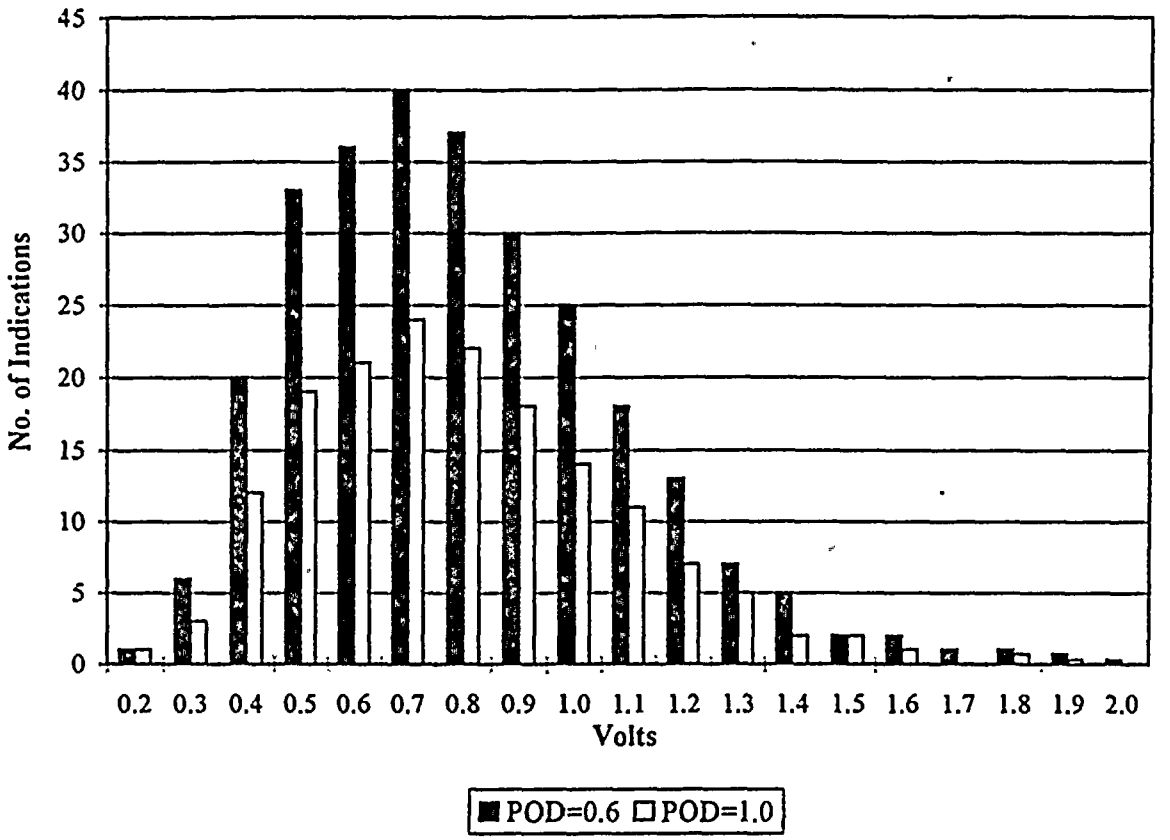


Figure 7-3. D.C. Cook-1: S/G 14 Projected EOC-14 Voltage Distributions
All Indications



9.0 REFERENCES

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3. NUREG-1477 (draft), "Voltage-Based Interim Plugging Criteria for Steam Generator Tubes - Task Group Report," United States Nuclear Regulatory Commission (NRC), June 1, 1993.

4. WCAP-13187, "D. C. Cook-1 Steam Generator Tube Plugging Criteria for Indications at Tube Support Plates," Westinghouse Electric Corporation, March 1992.

5. NP-7480-L, Volume 1, Revision 1, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Limits, Volume 1: 7/8 Inch Diameter Tubing," Electric Power Research Institute, December, 1993.

6. EPRI Letter, "Exclusion of Data from Alternate Repair Criteria (ARC) Databases Associated with 7/8 inch Tubing Exhibiting ODSCC," D. A. Steininger (EPRI) to J. Strosnider (USNRC), April 22, 1994 [to become Appendix E of reference (2)].

7. TR-100407, Revision 1 (draft), "PWR Steam Generator Tube Repair Limits - Technical Support Document for Outside Diameter Stress Corrosion Crack at Tube Support Plates," Electric Power Research Institute, August 1993.