ATTACHMENT 2 TO AEP:NRC:1166AI

COOK STEAM GENERATORS U1R97

2 VOLT INTERIM PLUGGING CRITERIA REPORT

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1.0 Introduction

This report provides the results of the Cook Unit 1 steam generator tube eddy current inspection as it applies to the voltage-based repair criteria of Generic Letter 95-05.

Per the requirements of GL 95-05, with two cycles of operating data available, the highest growth rate was used in calculations performed for the determination of the leak rate and probability of tube burst for the voltage distribution of the population of tube support plate indications that were returned to service for cycle 16. The methodology for these calculations is based upon WCAP-14277 Revision 1, which has been approved for use.

The application of the voltage-based T/S amendment for Unit 1 requires a 100% BC inspection of all in service tubes and subsequent RPC inspection of TSP indications greater than 2.0 volts for determination of the repair status of the indications. Plugging of indications greater than 5.6 volts TSP BC response is required regardless of RPC inspection confirmation. Calculation results of predicted SG tube leak rate and probability of burst during a postulated MSLB at EOC 16 are well below the applicable regulatory requirements.

The results of the calculations are based upon the distribution of indications that were detected at EOC 15, adjusted by the probability of detection of 0.6, and removing the repaired indications. The results of the calculations determined that the postulated conditions at EOC 16 are well below the requirements outlined in GL 95-05.

2.0 Summary and Conclusions

MSLB leak rate and tube burst probability analyses were performed for the actual EOC 15 BC voltage distributions and for projected EOC 16 distributions for each of the four Unit 1 SGs. The limiting SG at EOC 15 was determined to be SG 11, with the highest number of indications and the highest leak rate for the postulated MSLB. The tube burst probability at EOC 15 was low (1.6×10^{-5}), with 3 trials having at least one tube burst in 500,000 Monte Carlo simulations for SG 11 and SG 14. SG 11 is predicted to be limiting at EOC 16, with the highest number of indications and BC voltage amplitude and leak rate for the postulated MSLB. The tube burst probability at EOC 15 is low and varied between 9.7×10^{-6} and 2.1×10^{-5} between the four SGs. MSLB leak rates for the actual EOC 15 and projected EOC 16 distributions are 0.42 and 0.96 gpm in SG 11 and SG 14, respectively. These calculations demonstrate that the ARC application at EOC 15 (actual distribution) and at EOC 16 (predicted for POD=0.6) will satisfy the criteria for allowable leakage and burst probability.

A total of 1053 BC indications were reported in all SG's during the EOC 15 inspection. Of the 1053 indications, 131 were > 1.0 volt and all were less than 1.8 volts. The highest BC voltage recorded was 1.73 volts, so there were no indications above the 2.0 volt ARC repair limit. No indications were RPC inspected, (except the tube removal candidate). Tubes removed from service were based upon reasons other than ODSCC at

the TSP intersections. As a result, the total number of TSP indications returned to service for cycle 16 was 903.

SG 11 was limiting at EOC 15 with 369 indications from the tubes in service during cycle 15. Of the 369, 7 were reported as greater than 1.0 volt and less than the highest reported BC voltage of 1.73. Of the 369 indications, 47 were removed from service for reasons other than ODSCC at the TSP.

For the actual EOC 15 BC voltage distribution, the limiting MSLB tube leak rate is calculated to be 0.42 gpm and the limiting tube burst probability is less than 1.6×10^{-5} for SG 11, substantially lower than the Unit 1 T/S allowable MSLB tube leak limit and the reporting guideline for the tube burst probability contained in NRC report "Safety Evaluation by the Office of Nuclear Reactor Regulations related to Amendment No. 200 Facility Operating License DPR-58 Indiana Michigan Power Company Donald C. Cook Nuclear Plant, Unit 1 Docket No.50-315". The results of actual EOC 15 tube leak rate and burst probability are lower than corresponding predictions of 0.70 gpm (SG 11) and 2.9×10^{-5} (SG 13) performed at the BOC-15, demonstrating the conservatism of the prediction methodology.

Using the POD=0.6 criteria to calculate the performance of the limiting SG during the next Unit 1 operating cycle, the MSLB tube leak rate is projected to be 0.96 gpm and the limiting tube burst probability is less than 2.2×10^{-5} for SG 11 at EOC 16. The results are lower than the Unit 1 ARC requirement for allowable tube leakage and the NRC guideline for the tube burst probability; accordingly cycle 16 operation of Unit 1 is considered to be in compliance with requirements of the Cook Unit 1 T/S.

3.0 EOC 15 Inspection Results

3.1 As Found Conditions of SGs at EOC 15

In accordance with ARC guidance provided by GL 95-05, the EOC 15 ECT inspection of the SGs consisted of a 100% full length BC examination of all in service tubes for all four steam generators and included BC probe wear. Per GL 95-05 and our ARC SER, it was required that RPC confirmed indications of greater than 2.0 volts BC amplitude shall be plugged and those greater than 5.6 volts BC amplitude shall be plugged regardless of RPC confirmation. The highest DSI BC voltage reported during this inspection was 1.73 volts and was not RPC inspected, none of the tubes that were in service during cycle 15 required plugging for ODSCC at TSP intersections.

A summary of ECT indication distributions for all SGs is shown in Table 3-1. For those tubes that were in service during cycle 15, Table 3-1 provides the number of field BC indications, POD at 0.6, indications repaired, and the BOC-16 distribution.

- Of the in service tubes at the EOC 15, 1053 indications were identified during the inspection, 150 were removed from service for causes other than ODSCC at TSP intersections, leaving 903 tubes with DSI indications returning to service for cycle 16.

- Of the 1053 indications, no tubes required RPC inspection since all the voltage values were less than the 2.0 volt criteria.

- 131 indications were greater than 1.0 volt and less than or equal to 1.73 volts. Of those, 26 were repaired for causes other than ODSCC at TSP intersections.

SG 11 has the largest number of field indications and the largest number of field indications greater than 1.0 volt. Therefore, SG 11 is the limiting SG with SG 14 a close second. The largest BC indication was found in SG 12 (shown in the 1.8 volt bin).

3.2 Non Destructive Examination Uncertainties

The NDE uncertainties applied for both the as-found conditions and projected EOC 16 calculations are those prescribed in GL 95-05. The probe wear, or acquisition error, has a standard deviation of 7.0% with a mean of zero and a cutoff of 15% based upon implementation of a probe wear standard during the acquisition of the ECT data. The analyst variability uncertainty has a standard deviation of 10.3% with a mean of zero, and no cutoff. These NDE uncertainty distributions were included in both sets of calculations that were performed for the Unit 1 SGs (EOC 15 as-found and EOC 16 projections).

3.3 Voltage Growth Assessment

An assessment of the voltage growth of the indications due to defect progression was also performed, per GL 95-05. According to section 2.b.2(2) of the GL; voltage growth rates should only be evaluated for those indications which can be identified at two successive inspections. Additionally, the most limiting growth rate of either previous or current cycle should be used to estimate the growth for the next inspection cycle when both inspections meet the ECT data acquisition requirements in section 3 of GL 95-05.

For cycle 16 growth on Unit 1, the growth rates used are composite growth rates for each SG that consist of cycle 14 plus cycle 15 growth. Since cycle 14 data for all SG's consisted of less than 200 indications each, the data was combined with cycle 15 growth to determine a composite SG specific growth rate. The composite growth rates were then used as the estimated cycle 16 growth used in the tube integrity calculations. The SG specific growth rates used in the cycle 16 Monte Carlo analysis are contained in Table 3-9. Tables 3-5 through 3-8 provide the voltage growth for the last four operating cycles.

Table 3-1

Summary of Inspection and Repair for Tubes Inservice during Cycle 15

	Steam Generator 11			
	Summary of Inspection and Repair of Tubes			
Voltage Bin	Field Indications	POD = 0.6 Adjusted	Indications Repaired	BOC 16 Distribution
0.10	0	0.0	0	0.0
0.20	17	28.3	0	28.3
0.30	62	103.3	5	98.3
0.40	73	121.7	9	112.7
0.50	59	98.3	6	92.3
0.60	42	70.0	5	65.0
0.70	28	46.7	4	42.7
0.80	28	46.7	1	45.7
0.90	13	21.7	3	18.7
1.00	16	26.7	3	23.7
1.10	12	20.0	0	20.0
1.20	8	13.3	0	13.3
1.30	6	10.0	2	8.0
1.40	2	3.3	1	2.3
1.50	2	3.3	1	2.3
1.60	0	0.0	0	0.0
1.70	1	1.7	0	1.7
1.80	0	0.0	0	0.0
1.90	0	0.0	0	0.0
2.00	0	0.0	0	0.0
Total	369	615	40	575
>1V	31	52	4	48

	Steam Generator 12			
	Summary of Inspection and Repair of Tubes			
Voltage Bin	Field Indications	POD = 0.6 Adjusted	Indications Repaired	BOC 16 Distribution
0.10	1	1.7	0	1.7
0.20	14	23.3	2	21.3
0.30	25	41.7	2	39.7
0.40	21	35.0	0	35.0
0.50	24	40.0	5	35.0
0.60	21	35.0	3	32.0
0.70	14	23.3	0	23.3
0.80	10	16.7	2	14.7
0.90	7	11.7	2	9.7
1.00	9	15.0	2	13.0
1.10	6	10.0	2	8.0
1.20	7	11.7	2	9.7
1.30	5	8.3	0	8.3
1.40	2	3.3	1	2.3
1.50	1	1.7	0	1.7
1.60	1	1.7	0	1.7
1.70	0	0.0	0	0.0
1.80	1	1.7	0	1.7
1.90	0	0.0	0	0.0
2.00	0	0.0	0	0.0
Total	169	282	23	259
>1V	23	38	5	33

	Steam Generator 13			
	Summary of Inspection and Repair of Tubes			
Voltage Bin	Field Indications	POD = 0.6 Adjusted	Indications Repaired	BOC 16 Distribution
0.10	1	1.7	0	1.7
0.20	13	21.7	1	20.7
0.30	18	30.0	0	30.0
0.40	40	66.7	5	61.7
0.50	29	48.3	1	47.3
0.60	17	28.3	3	25.3
0.70	15	25.0	4	21.0
0.80	9	15.0	3	12.0
0.90	8	13.3	0	13.3
1.00	1	1.7	0	1.7
1.10	5	8.3	2	6.3
1.20	1	1.7	0	1.7
1.30	1	1.7	0	1.7
1.40	1	1.7	0	1.7
1.50	1	1.7	1	0.7
1.60	0	0.0	0	0.0
1.70	0	0.0	0	0.0
1.80	0	0.0	0	0.0
1.90	0	0.0	0	0.0
2.00	0	0.0	0	0.0
Total	160	267	20	247
>1V	9	15	3	12

	Steam Generator 14			
	Summary of Inspection and Repair of Tubes			
Voltage Bin	Field Indications	POD = 0.6 Adjusted	Indications Repaired	BOC 16 Distribution
0.10	0	0.0	0	0.0
0.20	22	36.7	7	29.7
0.30	56	93.3	7	86.3
0.40	63	105.0	9	96.0
0.50	69	115.0	19	96.0
0.60	34	56.7	2	54.7
0.70	28	46.7	5	41.7
0.80	28	46.7	6	40.7
0.90	14	23.3	3	20.3
1.00	11	18.3	2	16.3
1.10	16	26.7	5	21.7
1.20	5	8.3	0	8.3
1.30	4	6.7	0	6.7
1.40	1	1.7	0	1.7
1.50	1	1.7	1	0.7
1.60	2	3.3	0	3.3
1.70	1	1.7	0	1.7
1.80	0	0.0	0	0.0
1.90	0	0.0	0	0.0
2.00	0	0.0	0	0.0
Total	355	592	66	526
>1V	30	50	6	44

*No indications were repaired due to RPC confirmation. Tubes were repaired for other pluggable defects.

Table 3-2
Unit 1 1997 Outage
TSP ODSCC Indication Distribution for Tubes in Service during Cycle 15

Tube Support Plate	Steam Generator 11			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	213	1.65	0.58	0.000
2H	110	1.43	0.50	-0.007
3H	35	1.23	0.44	-0.019
4H	8	0.70	0.36	0.033
5H	1	0.21	0.21	0.020
6H	2	0.34	0.29	-0.030
7H	0	0.00	0.00	0.000
Total	369			

Tube Support Plate	Steam Generator 12			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	76	1.73	0.63	-0.088
2H	65	1.54	0.60	-0.024
3H	13	0.80	0.44	-0.036
4H	13	1.15	0.38	-0.008
5H	2	0.62	0.43	0.075
6H	0	0.00	0.00	0.000
7H	0	0.00	0.00	0.000
Total	169			

Tube Support Plate	Steam Generator 13			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	108	1.45	0.50	-0.089
2H	38	1.25	0.51	-0.073
3H	10	0.71	0.38	-0.049
4H	0	0.00	0.00	0.000
5H	4	0.45	0.29	-0.100
6H	0	0.00	0.00	0.000
7H	0	0.00	0.00	0.000
Total	160			

Tube Support Plate	Steam Generator 14			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	132	1.56	0.62	0.050
2H	135	1.58	0.51	0.028
3H	63	1.09	0.41	0.002
4H	19	1.62	0.47	0.056
5H	4	0.73	0.38	0.023
6H	0	0.00	0.00	0.000
7H	2	0.46	0.40	0.040
Total	355			

Tube Support Plate	Composite of All Four SGs			
	Number of Indications	Maximum Voltage	Average Voltage	Average Growth
1H	529	1.73	0.58	-0.032
2H	348	1.58	0.53	-0.019
3H	121	1.23	0.42	-0.025
4H	40	1.62	0.30	0.020
5H	11	0.73	0.33	0.004
6H	2	0.34	0.07	-0.008
7H	2	0.46	0.10	0.010
Total	1053			

Table 3-3
Cook Unit 1 1997 Outage
Average Voltage Growth History
Composite of All Steam Generator Data

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percent Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
	Cycle 15 (1995-1997) - 429.06 EFPD					
Entire Voltage Range	1053	0.54	-0.011	-0.009	-2.0%	-1.7%
V_{BOC} <0.75 Volts	831	0.42	0.012	0.010	2.9%	2.4%
≥ 0.75 Volts	222	1.01	-0.096	-0.082	-9.5%	-8.1%
	Cycle 14 (1994-1995) - 390.54 EFPD					
Entire Voltage Range	597	0.62	0.034	0.031	5.4%	5.1%
V_{BOC} <0.75 Volts	445	0.50	0.031	0.029	6.3%	5.8%
≥ 0.75 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} <0.75 Volts	356	0.50	0.000	0.000	0.0%	0.0%
≥ 0.75 Volts	158	0.95	0.030	0.025	2.6%	2.1%
	Cycle 12 (1990-1992) - 445 EFPD					
Entire Voltage Range	201	1.00	0.020	0.016	1.6%	1.3%
V_{BOC} <0.75 Volts	30	0.67	0.080	0.064	9.6%	7.7%
≥ 0.75 Volts	171	1.07	0.010	0.008	0.8%	0.6%

Table 3-4
Cook Unit 1 1997 Outage
Average Voltage Growth during Cycle 15

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percent Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
	Composite of All Steam Generator Data					
Entire Voltage Range	1053	0.54	-0.011	-0.009	-2.0%	-1.7%
V_{BOC} <0.75 Volts	831	0.42	0.012	0.010	2.9%	2.4%
≥ 0.75 Volts	222	1.01	-0.096	-0.082	-9.5%	-8.1%
	Steam Generator 11					
Entire Voltage Range	369	0.54	-0.003	-0.003	-0.6%	-0.5%
V_{BOC} <0.75 Volts	291	0.42	0.022	0.019	5.2%	4.5%
≥ 0.75 Volts	78	1.00	-0.096	-0.082	-9.6%	-8.2%
	Steam Generator 12					
Entire Voltage Range	169	0.63	-0.052	-0.044	-8.3%	-7.0%
V_{BOC} <0.75 Volts	112	0.42	-0.011	-0.009	-2.6%	-2.2%
≥ 0.75 Volts	57	1.06	-0.131	-0.111	-12.4%	-10.5%
	Steam Generator 13					
Entire Voltage Range	160	0.57	-0.083	-0.071	-14.6%	-12.4%
V_{BOC} <0.75 Volts	130	0.46	-0.051	-0.043	-11.1%	-9.4%
≥ 0.75 Volts	30	1.05	-0.220	-0.187	-21.0%	-17.8%
	Steam Generator 14					
Entire Voltage Range	355	0.50	0.033	0.028	6.6%	5.6%
V_{BOC} <0.75 Volts	298	0.41	0.039	0.033	9.5%	8.1%
≥ 0.75 Volts	57	0.97	0.003	0.002	0.3%	0.3%

Table 3-5
Cook Unit1
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 3-6
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 3-7
Cook Unit 1
Signal Growth Statistics for Cycle 14 ('94 to '95) 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	2	0.017	0	0
-0.1	7	0.035	6	0.066	2	0.22
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 disrtibution for SG-11 plus the largest growth observed, which is in SG-12.

Table 3-8
Cook Unit 1
Signal Growth Statistics for Cycle 15 ('95 to '97) 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
-0.5	2	0.005	2	0.012	2	0.013
-0.4	3	0.014	4	0.036	1	0.019
-0.3	4	0.024	0	0.036	4	0.044
-0.2	11	0.054	12	0.107	11	0.113
-0.1	38	0.157	20	0.225	32	0.313
0	147	0.556	67	0.621	71	0.756
0.1	106	0.843	54	0.941	29	0.938
0.2	34	0.935	7	0.982	8	0.988
0.3	16	0.978	3	1	2	1
0.4	4	0.989				
0.5	3	0.997				
0.6	1	1				
Total	369		169		160	

Delta Volts	Steam Generator 14		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	2	0.006	8	0.008
-0.4	0	0.006	8	0.015
-0.3	1	0.008	9	0.024
-0.2	7	0.028	41	0.063
-0.1	22	0.090	112	0.169
0	109	0.397	394	0.543
0.1	144	0.803	333	0.859
0.2	47	0.935	96	0.951
0.3	15	0.977	36	0.985
0.4	6	0.994	10	0.994
0.5	2	1	5	0.999
0.6			1	1
Total	355		1053	

Table 3-9
Cook Unit 1
Voltage Growth Statistics for Cycle 16 ('97 to '98) used in Monte Carlo Analysis

Delta Volts	Steam Generator 11		Steam Generator 12		Steam Generator 13	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	2	0.0035	2	0.0069	2	0.008
-0.4	3	0.0088	4	0.0207	1	0.012
-0.3	4	0.0158	0	0.0207	4	0.0280
-0.2	11	0.0352	14	0.0690	11	0.0720
-0.1	45	0.1144	26	0.1586	34	0.2080
0	204	0.4736	114	0.5517	103	0.6200
0.1	187	0.8028	99	0.8931	70	0.9000
0.2	70	0.9261	19	0.9586	21	0.9840
0.3	29	0.9771	9	1	4	1
0.4	6	0.9877	1	0.9931		
0.5	5	0.9965	1	0.9966		
0.6	2	1	0	0.9966		
0.7			1	1		
Total	568		290		250	

Delta Volts	Steam Generator 14		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF
-0.5	2	0.0037	8	0.0049
-0.4	0	0.0037	8	0.0097
-0.3	3	0.0092	11	0.0164
-0.2	8	0.0240	44	0.0431
-0.1	30	0.0793	135	0.1249
0	173	0.3985	594	0.4851
0.1	234	0.8303	590	0.8429
0.2	66	0.9520	176	0.9497
0.3	17	0.9834	59	0.9854
0.4	6	0.9945	13	0.9933
0.5	3	1	9	0.9988
0.6			2	1.0000
0.7			1	1
Total	542		1650	

Figure 3 - 1

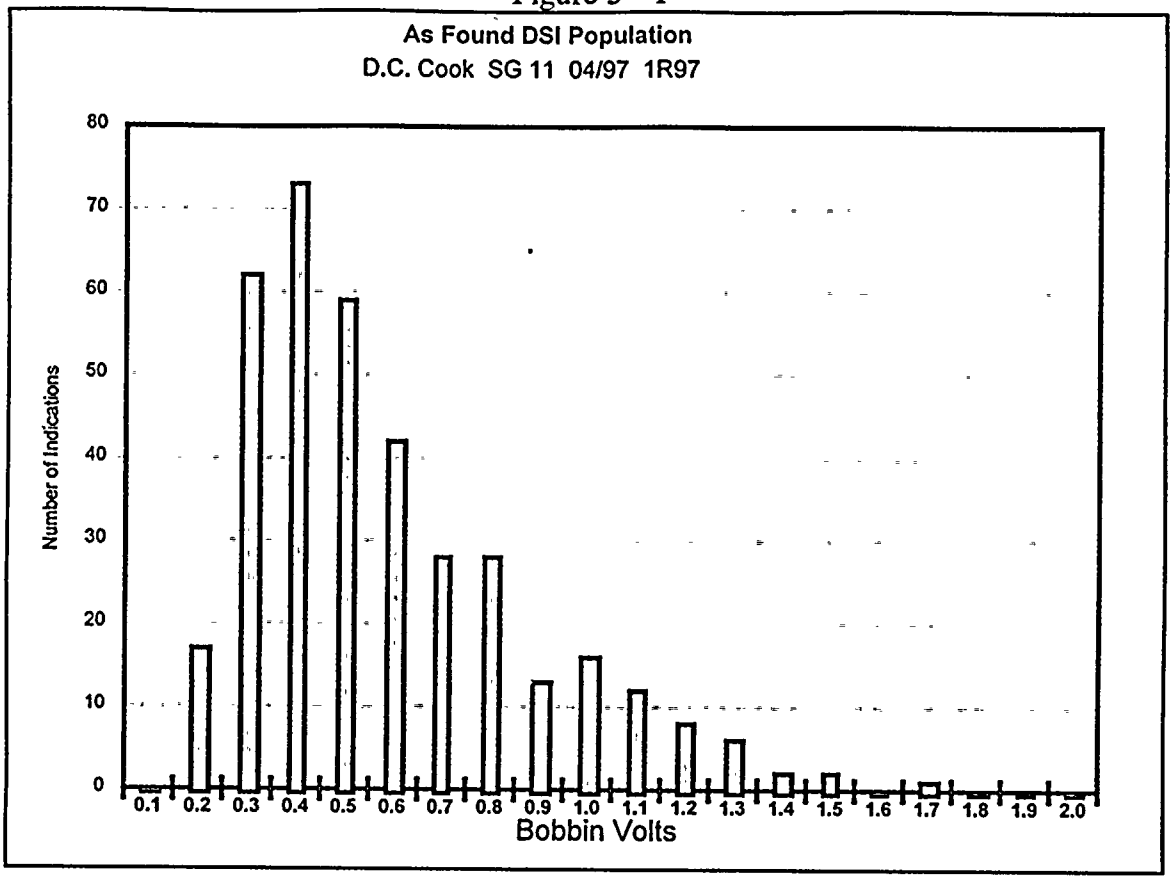


Figure 3 - 2

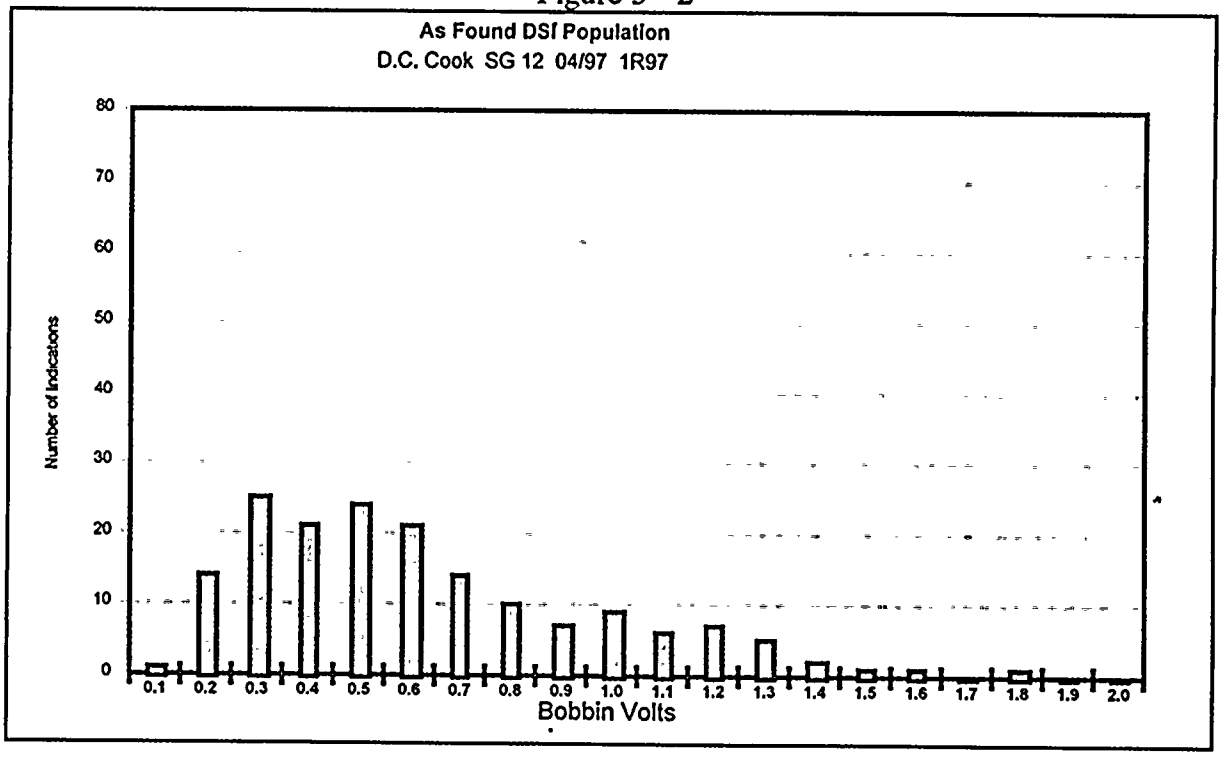


Figure 3-3

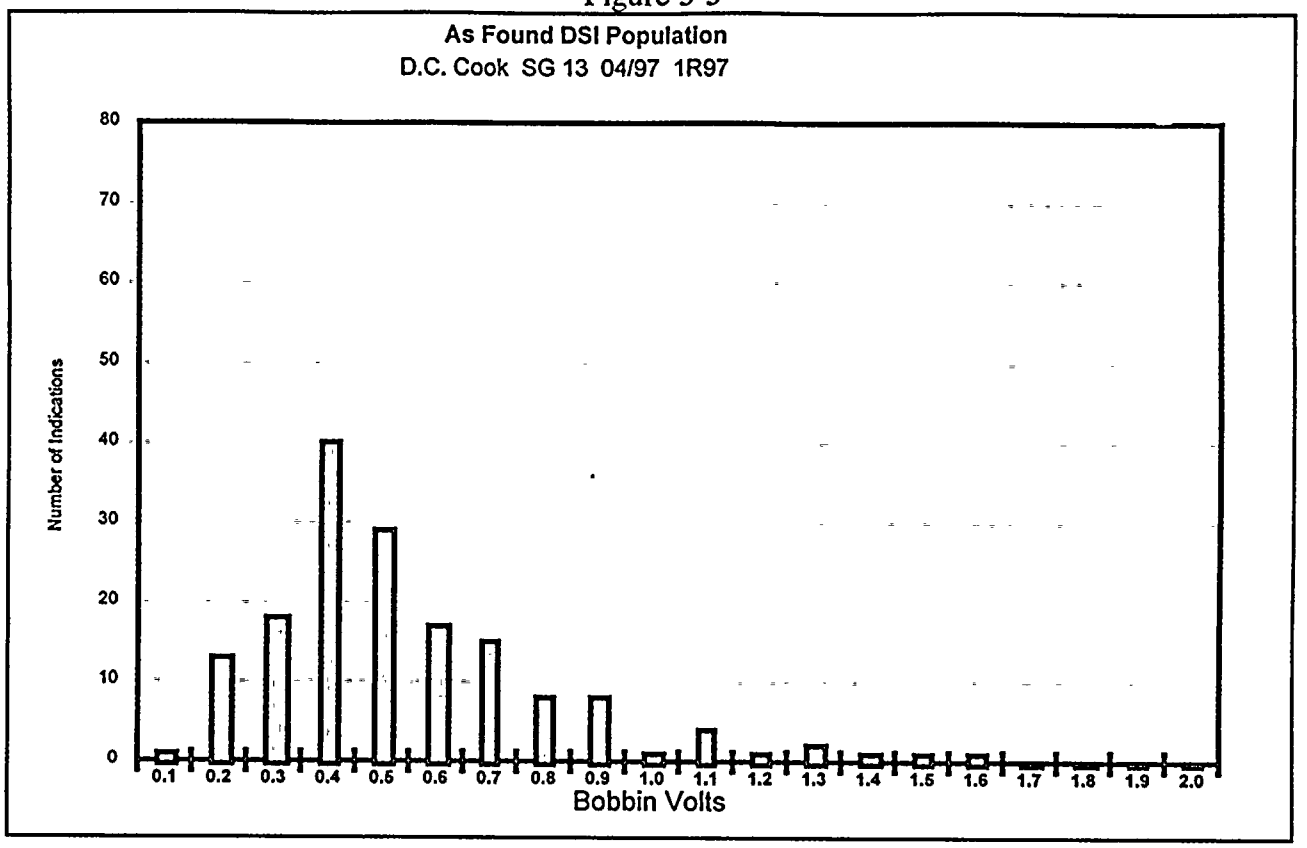


Figure 3-4

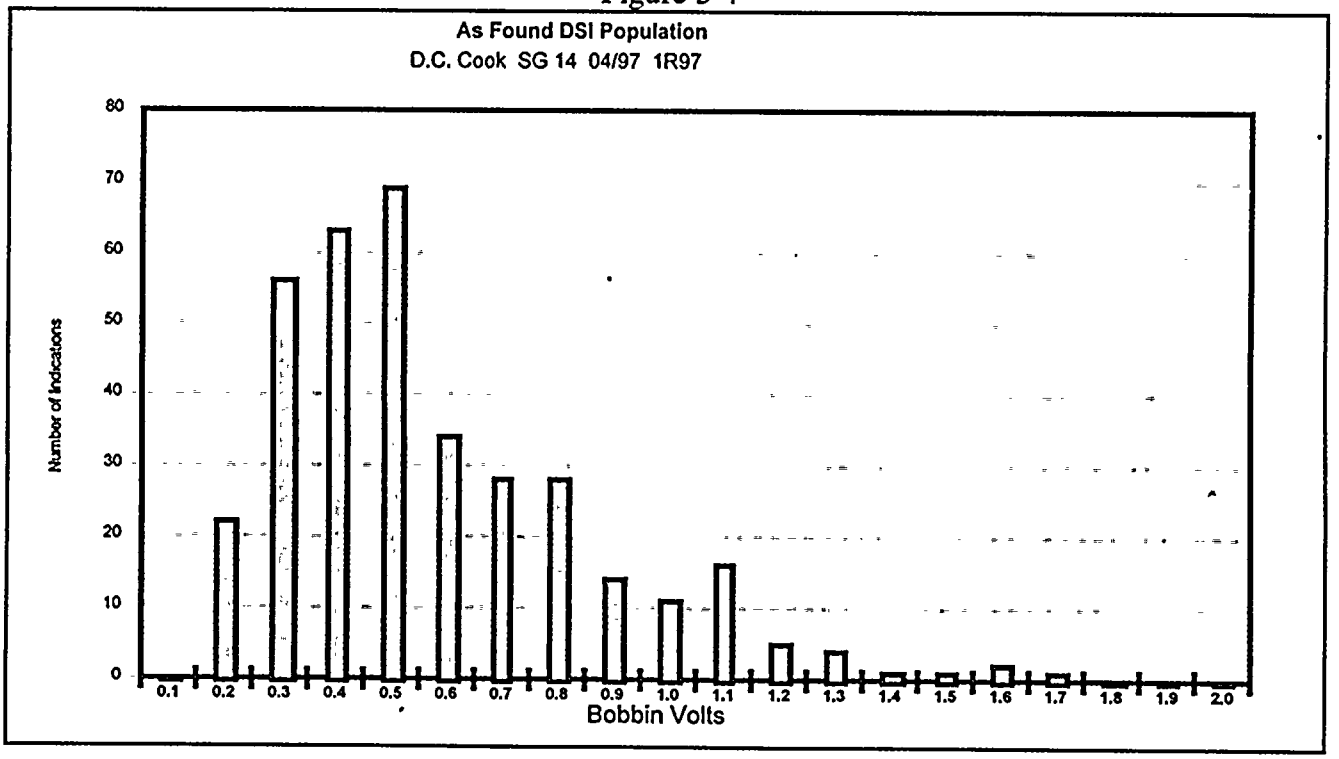


Figure 3-5

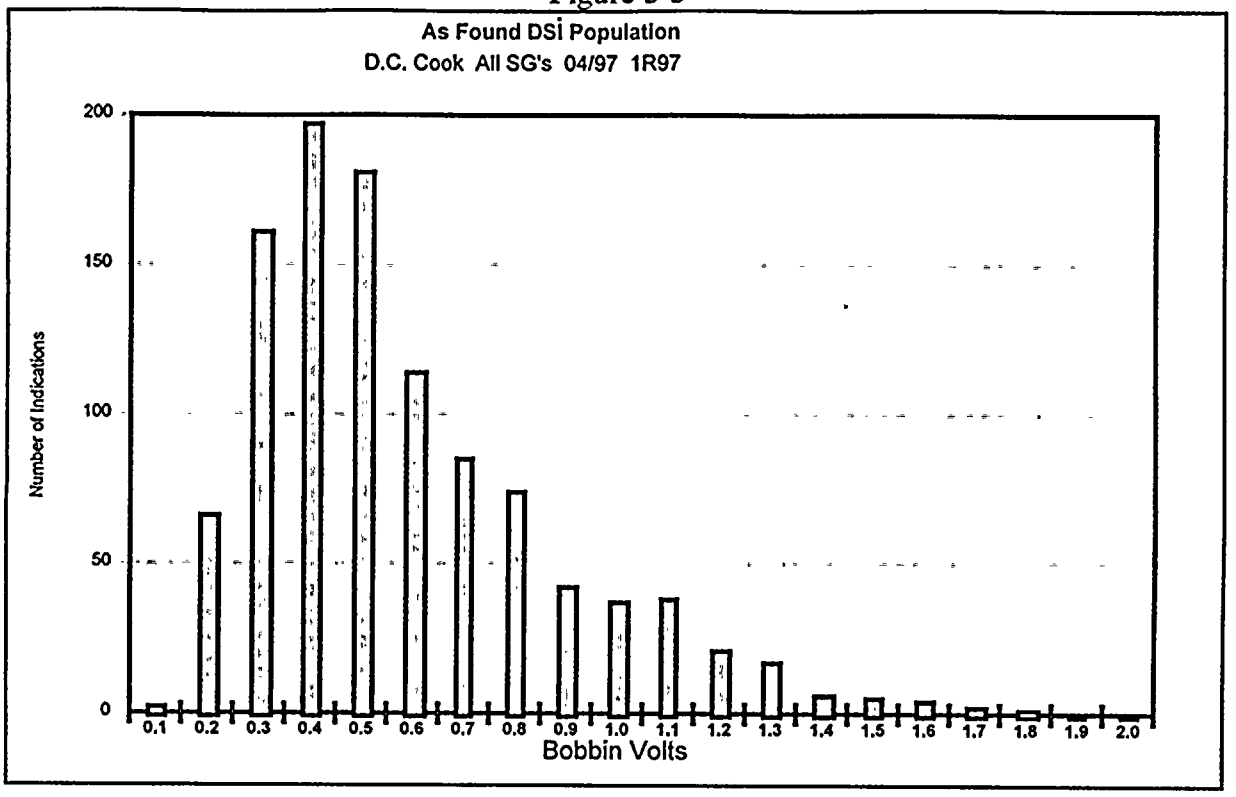

As Found DSI Population
D.C. Cook All SG's 04/97 1R97
Number of Indications
200
150
100
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Bobbin Volts

Figure 3-6

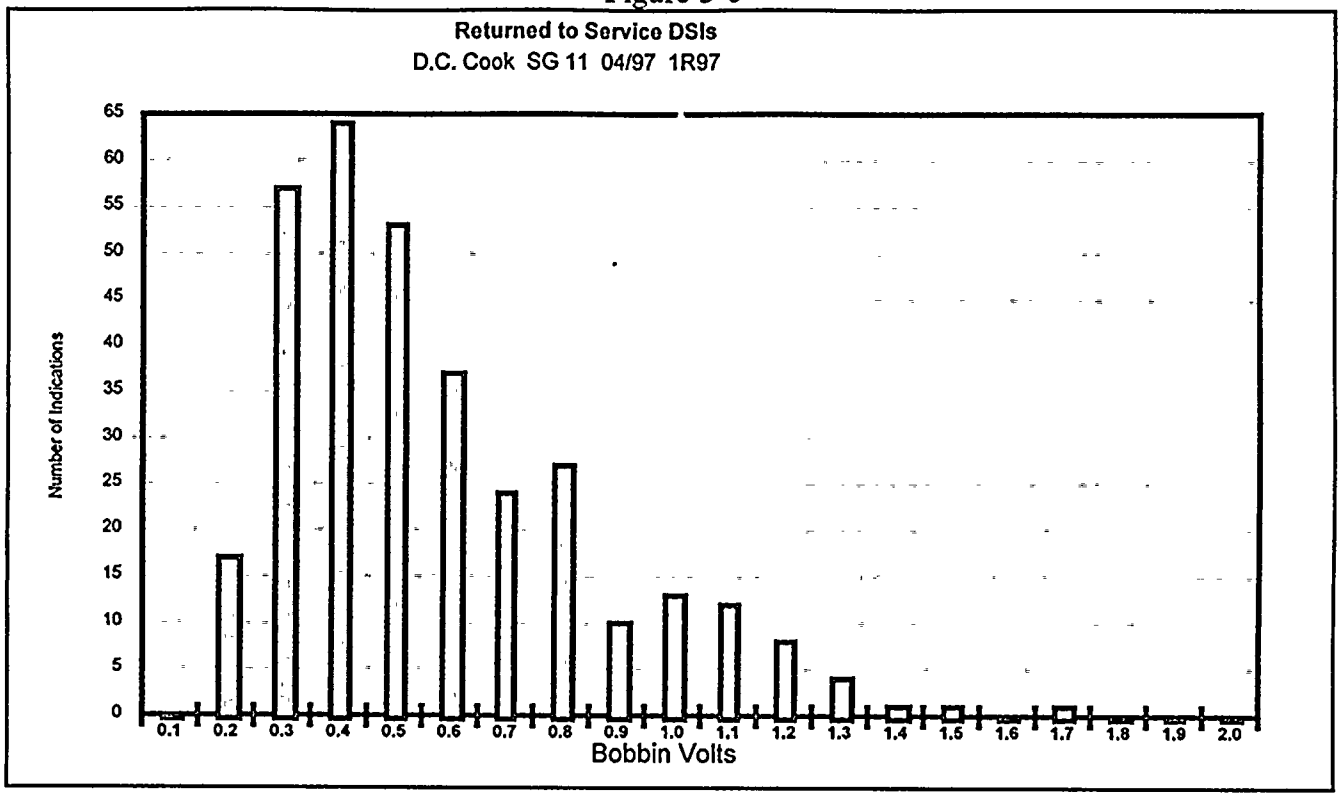


Figure 3-7

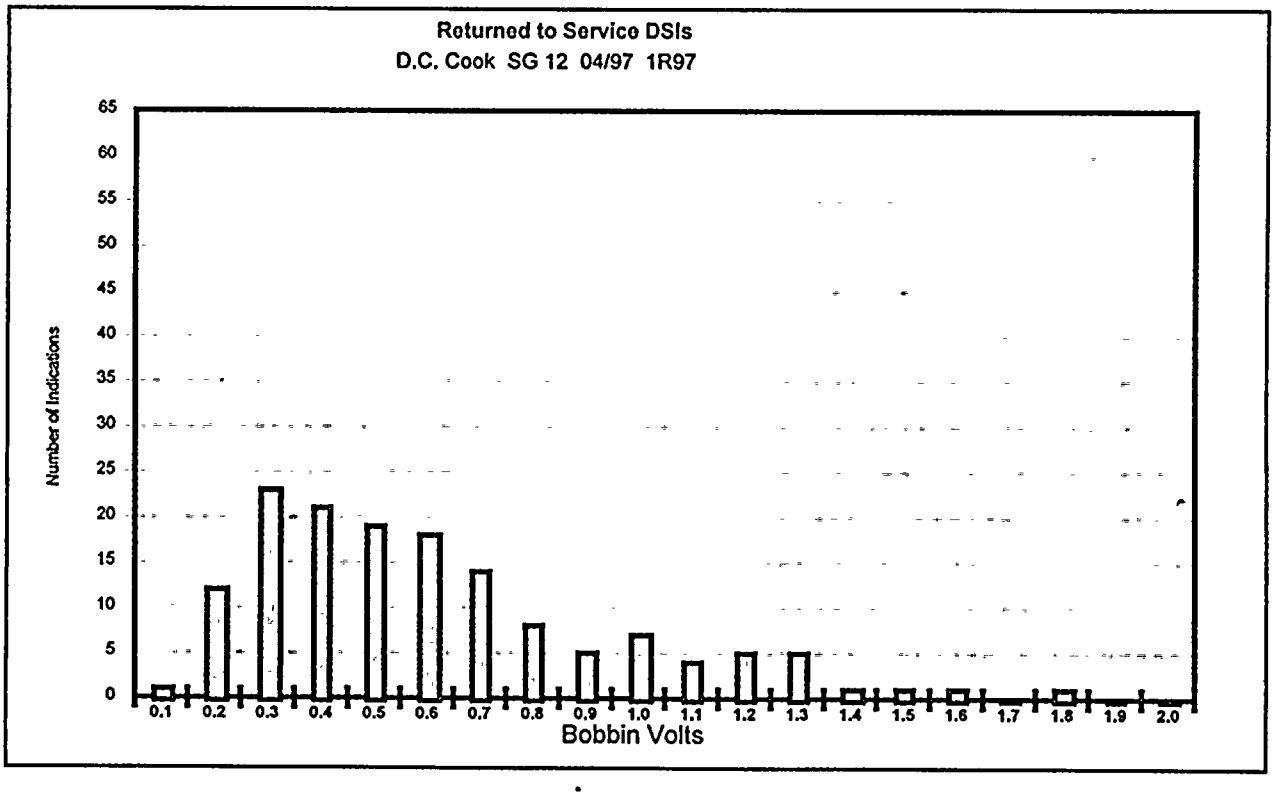


Figure 3-8

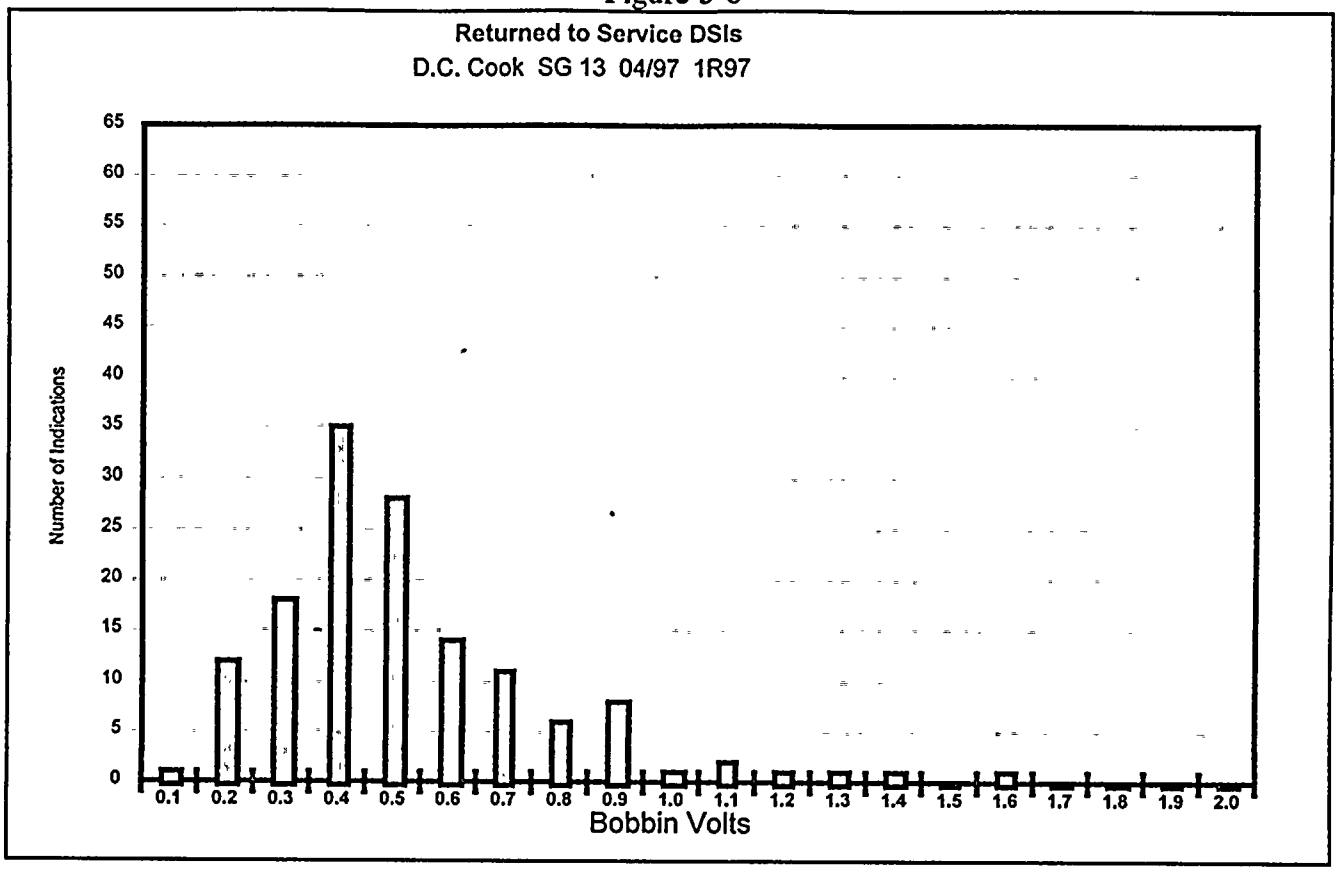


Figure 3-9

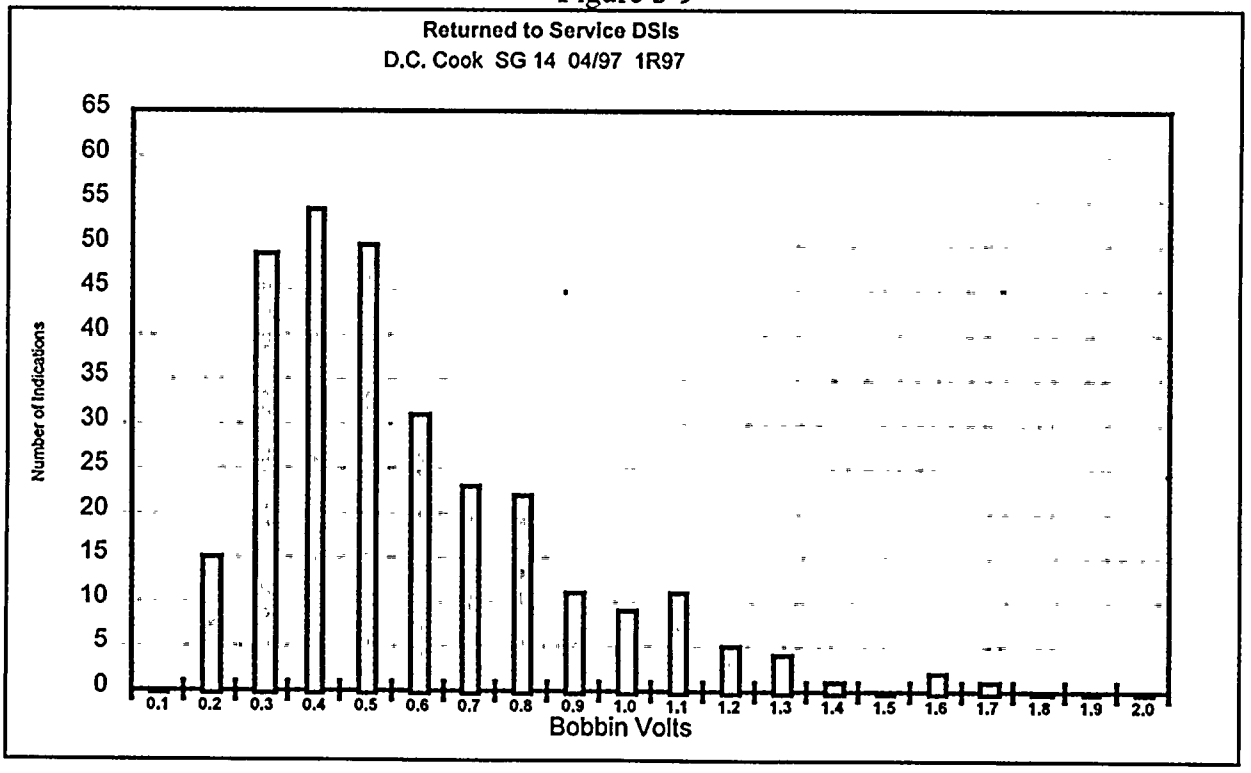


Figure 3-10

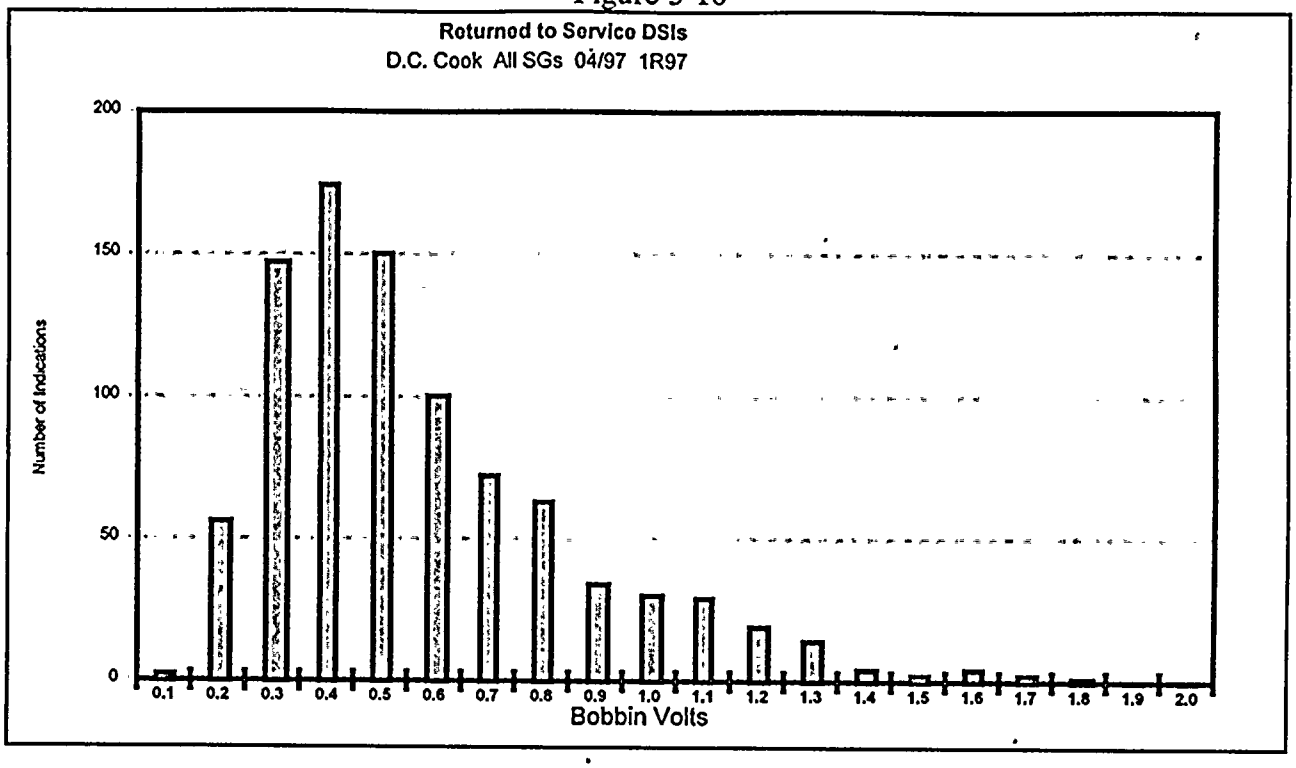

Returned to Service DSIs
D.C. Cook All SGs 04/97 1R97
Number of Indications
200
150
100
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Bobbin Volts

Figure 3-11

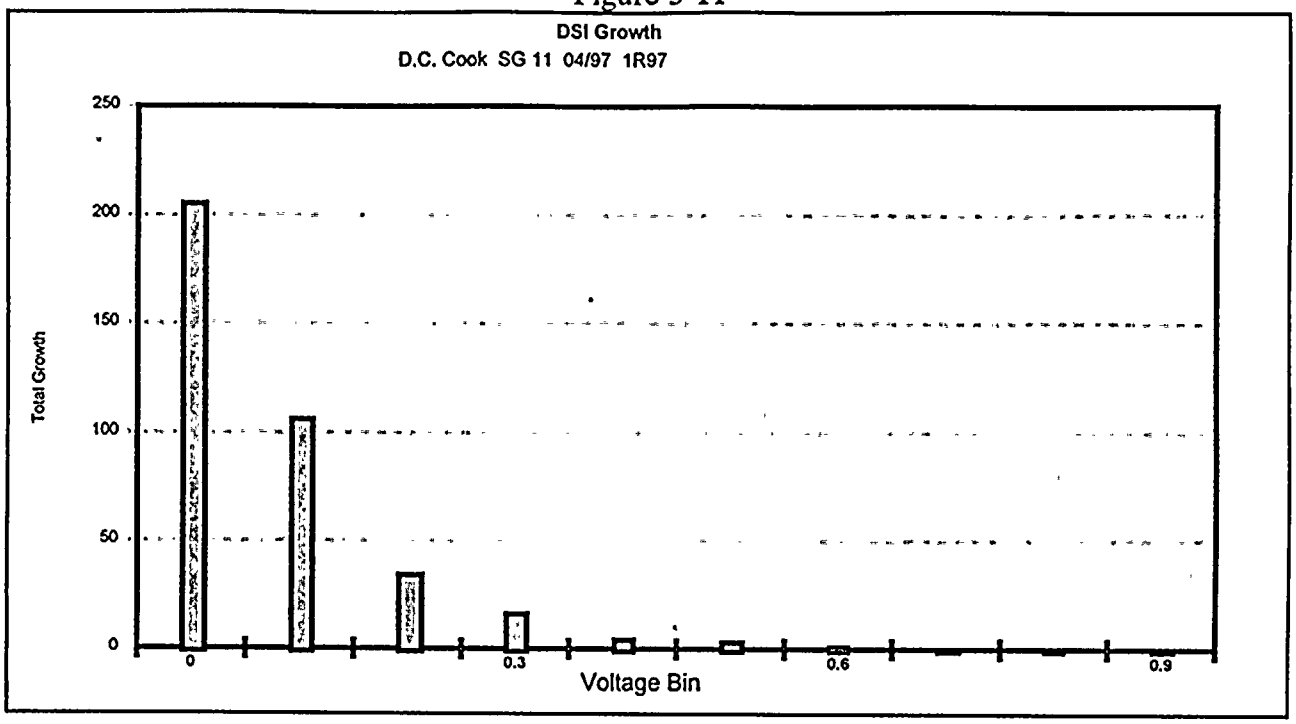


Figure 3-12

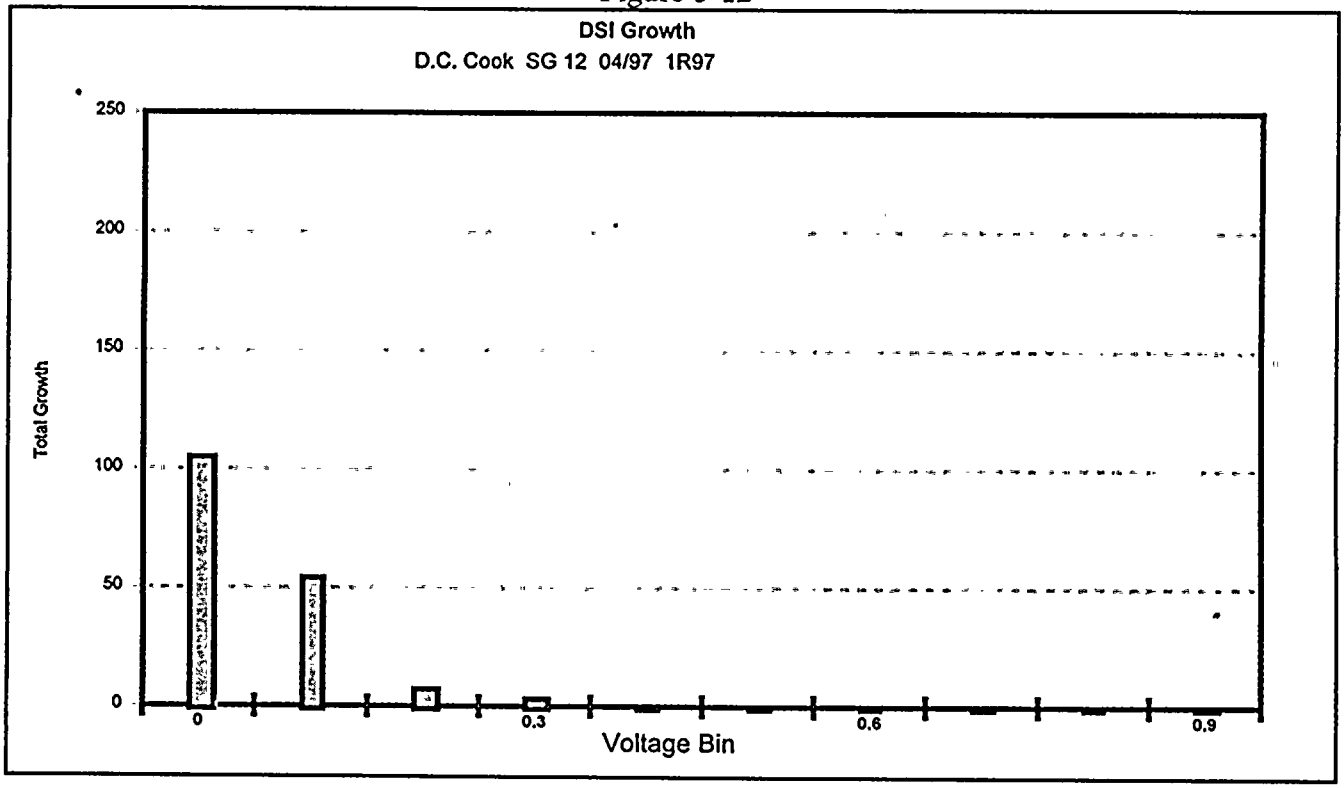


Figure 3-13

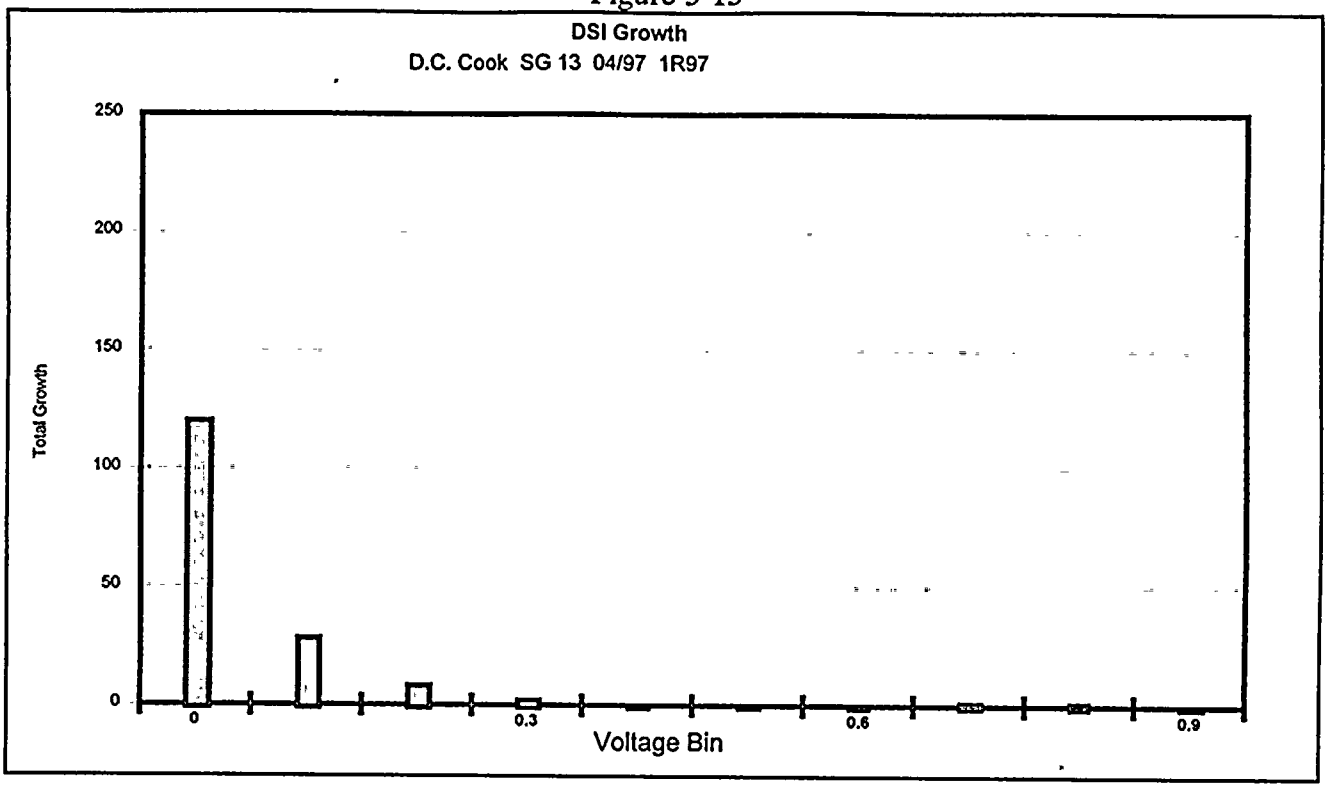


Figure 3-14

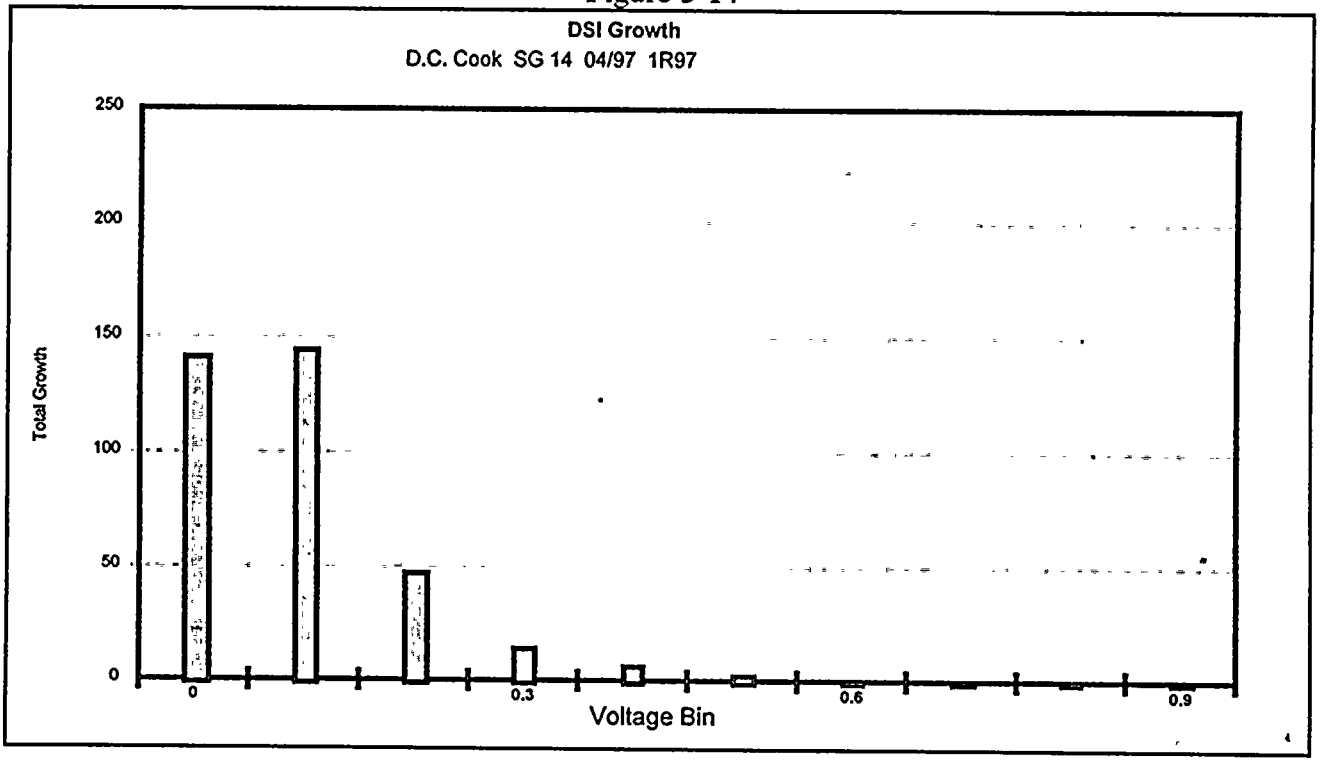
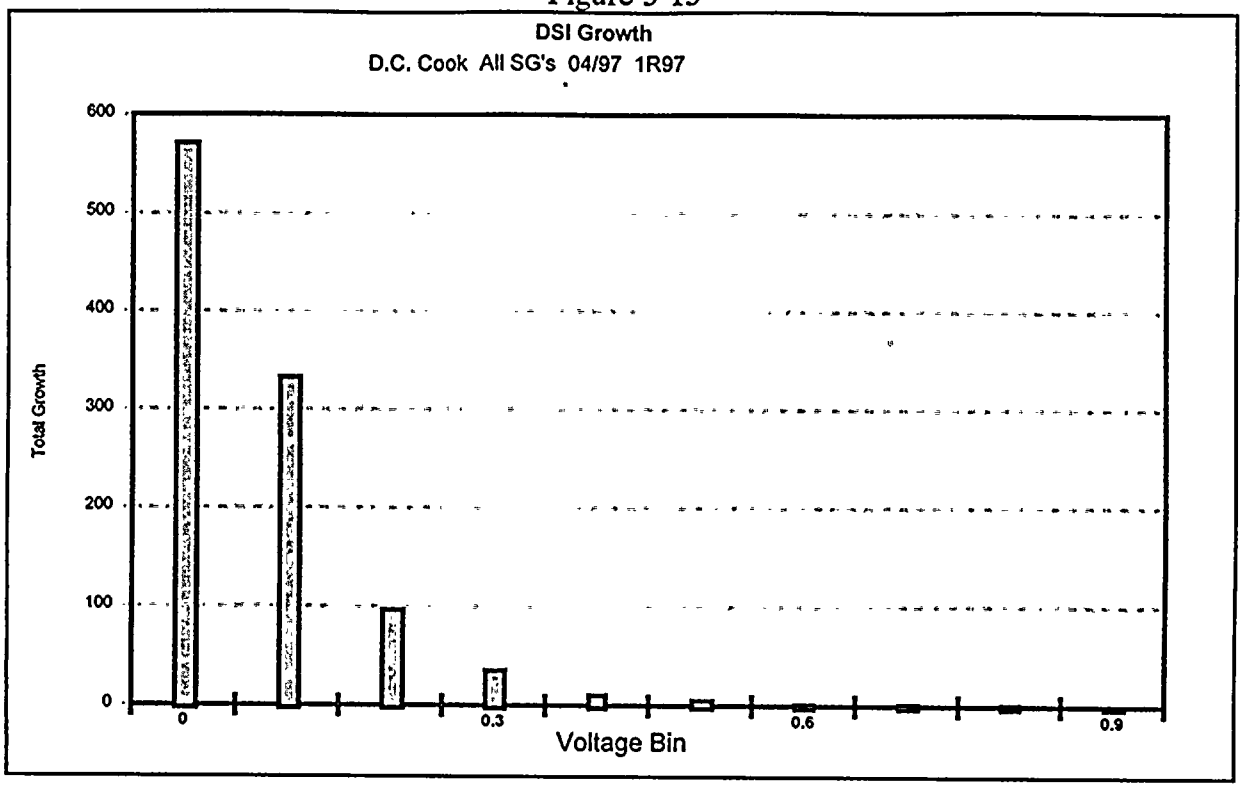


Figure 3-15


DSI Growth
D.C. Cook All SG's 04/97 1R97
Total Growth
600
500
400
300
200
100
0
0
0.3
0.6
0.9
Voltage Bin

4.0 Database Applied for Safety Evaluation Report Correlation

The database used for the correlation's that are applied in the analyses of this report are consistent with GL 95-05 and the NRC SER applicable to the Cook Unit 1 EOC 15 inspection. The database used for the calculation reported in this document is the database submitted to the NRC on March 27, 1996 by DLCO. This database was interpreted as the latest "approved" industry database. Additionally, this database contains French plant data and for leakage, does not meet GL 95-05 requirements for a correlation (p value is greater than 5%), thus producing conservative leak rate results.

For the MSLB leak rate correlation, the methodology used is that described in Revision 1 of WCAP-14277, for calculating the SG tube leakage from the faulted SG during a postulated MSLB event. The model consists of two major components: (1) a model predicting the probability that a given indication will leak as a function of voltage and (2) a model predicting leak rate as a function of voltage, given that leakage occurs. This methodology is consistent with the guidance in GL 95-05.

Correlation's have been developed for the evaluation of ODSCC indications at TSP locations in SGs of nuclear power plants which relate BC voltage amplitudes, free span burst pressure, probability of leakage and associated leak rates. The methodology used in the calculation of these parameters, is consistent with NRC criteria and guidelines of GL 95-05.

The analysis process starts with the receipt of BC voltage from the site ECT inspection team. The site data consists of electronic files which include row, column, TSP identification number, and BC voltage. The data is sorted by BC 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. The reference to "volts" in this report invariably applies to "voltage bins," when cited to one significant digit after the decimal, i.e. 1.8 volts. The true value of an indication would be cited to two significant digits after the decimal, i.e., 1.71 volts.

The calculation consists of determining the initial conditions, the BC 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 the operating time, the limiting tube conditions occur at the end of any given time period or cycle.

5.0 Leak Rate and Probability of Burst

A Monte Carlo simulation was used to predict the EOC 16 voltage distributions and to calculate the MSLB leak rates and tube burst probabilities for both the actual EOC 15 voltage distribution and the predicted EOC 16 voltage distribution. These methods are consistent with the requirements of the Cook Unit 1 NRC SER and the generic methods report of WCAP-14277.

Based on the NRC SER recommended leak rate data base, the leak rate in the March 27, 1996 DLCO letter to the NRC which provided supplemental tube pull data supporting the alternate tube plugging criteria, does not satisfy the requirement for applying the MSLB leak rate verses BC voltage correlation. The NRC requirement is that the *p* value obtained from the regression for the slope parameter be less that 5%. For the NRC recommended data, the *p* value of 6.5% and leak rate versus voltage correlation is not applied. The MSLB leak rate correlation applied is based on an average of all leak rate data independent of voltage. The analysis is similar to that of draft NUREG-1477 except for the uncertainty treatment.

For the case of the burst pressure versus voltage correlation, the database contained in the aforementioned DLCO letter meets all GL 95-05 requirements and was used in cycle 16 calculations. Material properties were also considered as part of the calculations and were obtained from a December 13, 1996 Westinghouse letter and advance copy of WCAP 14277 Revision 1 (AEP-96-183).

Table 5-1

Effect of Additional Data on the 7/8" Tube Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = \alpha_1 + \alpha_2 \log(Volts)$$

Parameter	Database
α_1	8.278
α_2	-2.584
r^2	81.8%
σ_{Error}	0.9034
N (data pairs)	80
p Value for α_2	1.3×10^{-30}
Reference σ_f	75

Notes: (1) This is the flow stress value to which all data was normalized prior to performing the regression analysis. This affects the coefficient and standard error values. The corresponding values for a flow stress of 75.0 ksi can be obtained from the above values by multiplying by 1.0904.

Table 5-2
7/8" Tube Probability of Leak Correlation
$Pr(Leak) = \{1 + e^{-[\beta 1+\beta 2 \log(V)]}\}^{-1}$

Parameter	Database
β_1	-6.2269
β_2	7.7739
V_{11} (1)	2.2911
V_{12}	-2.6004
V_{22}	3.2955
DoF (2)	107
Deviance	28.90
Pearson SD	59.4%

Notes:

(1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation.
(2) Degrees of freedom.

Table 5-3
Leak Rate Database for 7/8" Tube ARC Applications

Parameter	Leak Rate (lph)	Log (Leak Rate)[1]
	Database	Database
Sample Size	27	27
Sample μ	13.32	0.5696
Sample σ	20.84	0.8188
p Value	----------	6.4%

Notes:

(1) It has been previously shown that a log-normal distribution can be used to describe the population of leak rates.

6.0 Bobbin Voltage Distributions

The number of BC voltage indications used to predict tube leak rate and burst probability is obtained by adjusting the number of reported indications to account for non-detected cracks which could potentially leak or rupture under MSLB conditions during the next cycle. This is accomplished by using a probability of detection 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 and is defined as:

$$N_{TotRTS} = \frac{N_i}{POD} - N_{repaired} + N_{deplugged}$$

Where:

$N_{tot\ RT/S}$ = Number of BC indications returned to service for the next cycle.

N_i = Number of BC indications reported from last cycle inservice tubes.

POD = Probability of Detection.

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

$N_{deplugged}$ = Number of previously plugged tubes were deplugged and returned to service.

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.

6.1 Cycle Operating Time

The operating periods used in the previous and current voltage projection calculations are:

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

Cycle 15 = 429.06 EFPD Cycle 16 (projected)= 482 EFPD equals 1.32 EFPY.

6.2 Calculation of Voltage Distributions

BC voltage projections start with a cycle initial voltage distribution which is projected to the corresponding cycle final voltage distribution, based on the growth rates for each of the Unit 1 SG's during the previous two operating periods, as represented by their cumulative probability distribution functions. The 1995 - 1997 (cycle 15) growth rates were combined with those of the 1994 - 1995 (cycle 14) operation and are used to predict the EOC 16 bobbin voltage distributions. Growth rates were based upon steam generator specific voltage growth from cycle 14 and 15, in order to meet GL 95-05 requirements. The simulation for determining EOC voltages is consistent with the methods presented in the aforementioned AEP-96-183.

For each SG, the initial BC voltage distribution of indications being returned to service for the next cycle (BOC-16) is derived from the actual EOC 15 inspection results adjusted for tubes that are either (a) taken out of service by plugging, or (b) have been recovered for cycle 16 by deplugging of tubes plugged in previous outages on the basis of prior repair criteria. Note: No tubes were deplugged and returned to service for the BOC-16. The cycle 16 bobbin

voltage population, summarized on Table 3-1, shows EOC 15 bobbin voltage indications; the subsequent plugged indications (which were in service for cycle 15 and then taken out of service, albeit not for reasons of ODSCC at TSP); and also shows the BOC-16 indications corresponding to PODs of 0.6 and the EPRI lower 95% confidence limit.

6.3 Predicted EOC 16 Voltage Distributions

Calculation of the predicted EOC 16 BC voltage distributions was performed for all SGs with two different detection factors represented by:

POD = 0.6, in accordance with NRC direction.

POD = EPRI, a voltage based probability developed by EPRI

Using the methodology previously described, analyses were performed to predict the performance of the Unit 1 SGs at EOC 16, based on the BOC-16 summarized in Table 3-1 and the estimated cycle 16 growth distribution. The EPRI developed voltage dependent POD is based on expert opinion and multiple analysts' evaluations for the plants with 3/4" diameter tubes. The EPRI POD is applied for sensitivity analysis and for comparison with POD=0.6. The BOC-16 ARC voltage distributions are summarized on Table 6-1, for POD=0.6, and for the EPRI POD which is the order of decreasing detection uncertainty. 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 SG is SG 11 with 344 indications predicted for POD=0.6. For each generator, the BOC 16 actual and the EOC 16 predicted bobbin voltage frequency distributions are shown on Figures 6-1, 6-2, 6-3 and 6-4 respectively. The maximum bobbin voltage predicted for EOC 16 is 2.4 volts for POD=0.6 in SG 14.

6.4 Comparison of Predicted and Actual EOC 15 Voltage Distribution

The actual EOC 15 bobbin voltage distributions and the corresponding predictions, summarized on Table 6-1 provide a comparison of detection probability factors represented by the two PODs used in the EOC 15 predictions. As expected, using the POD of 0.6 provides a conservative estimate for the larger (> 1.0 volt) indications in each steam generator compared to the EPRI POD. The EPRI POD provides a better estimate in the number of large indications expected at the next cycle because of the higher individual POD of the large indications.

The frequency table generated by the Monte Carlo analysis was used to determine the number of indications at EOC 16. Figures 6-1, 6-2, 6-3 and 6-4 represent the projected number of indications per voltage bin for the EOC 16.

Table 6-2 summarizes the estimated distributions at EOC 16 for each steam generator. These distributions are considered as a conservative estimate for the projected population of indications at EOC 16.

Table 6-1
EOC 15 Actual and Projected Indications

Steam Generator 11			
Voltage	Actual	Projected With	
Bin	EOC-15	POD=0.6	POD=EPRI
0.1	0	0.1	0.1
0.2	17	1.7	3.1
0.3	62	6.1	8.5
0.4	73	20.5	23.4
0.5	59	39.4	41.4
0.6	42	46.1	46.0
0.7	28	45.7	43.0
0.8	28	42.0	37.4
0.9	13	36.0	30.5
1.0	16	29.0	24.1
1.1	12	23.1	18.3
1.2	8	17.0	13.2
1.3	6	12.0	9.3
1.4	2	8.2	6.3
1.5	2	5.5	4.1
1.6	0	3.7	2.7
1.7	1	2.5	1.8
1.8	0	1.7	1.2
1.9	0	1.1	0.8
2.0	0	0.7	0.3
2.1	0	0.1	0.0
2.2	0	0.7	0.7
2.3	0	0.0	0.3
2.4	0	0.3	0.0
Total	369	344	317
>1V	31	77	59

Steam Generator 12			
Voltage	Actual	Projected With	
Bin	EOC-15	POD=0.6	POD=EPRI
0.1	1	0.1	0.2
0.2	14	2.6	4.7
0.3	25	8.1	11.6
0.4	21	14.8	18.0
0.5	24	18.5	20.4
0.6	21	21.6	21.7
0.7	14	23.5	21.9
0.8	10	22.8	20.1
0.9	7	20.6	17.3
1.0	9	17.9	14.5
1.1	6	14.5	11.5
1.2	7	11.1	8.7
1.3	5	8.5	6.5
1.4	2	6.7	5.2
1.5	1	5.5	4.3
1.6	1	4.4	3.4
1.7	0	3.2	2.5
1.8	1	2.2	1.7
1.9	0	1.4	1.1
2.0	0	0.8	0.5
2.1	0	0.1	0.0
2.2	0	0.7	0.7
2.3	0	0.0	0.3
2.4	0	0.3	0.0
Total	169	210	196
>1V	23	59	46

Steam Generator 13			
Voltage	Actual	Projected With	
Bin	EOC-15	POD=0.6	POD=EPRI
0.1	1	0.0	0.0
0.2	13	0.9	1.7
0.3	18	4.1	5.6
0.4	40	10.4	12.1
0.5	29	17.7	18.8
0.6	17	21.9	21.8
0.7	15	22.2	20.9
0.8	9	19.2	17.2
0.9	8	14.8	12.7
1.0	1	11.3	9.3
1.1	5	8.9	7.0
1.2	1	7.0	5.5
1.3	1	5.4	4.2
1.4	1	3.9	3.0
1.5	1	2.6	2.0
1.6	0	1.6	1.2
1.7	0	0.9	0.5
1.8	0	0.1	0.0
1.9	0	0.7	0.7
2.0	0	0.0	0.3
2.1	0	0.3	0.0
2.2	0	0.0	0.0
Total	160	154	145
>1V	9	31	24

Steam Generator 14			
Voltage	Actual	Projected With	
Bin	EOC-15	POD=0.6	POD=EPRI
0.1	0	0.0	0.1
0.2	22	1.5	2.4
0.3	56	11.2	15.2
0.4	63	23.7	28.1
0.5	69	32.7	35.4
0.6	34	40.5	40.4
0.7	28	43.4	40.6
0.8	28	39.1	34.8
0.9	14	31.9	27.1
1.0	11	25.3	20.5
1.1	16	19.3	15.2
1.2	5	14.3	11.1
1.3	4	10.4	7.9
1.4	1	7.3	5.5
1.5	1	5.0	3.7
1.6	2	3.3	2.4
1.7	1	2.0	1.5
1.8	0	1.2	0.9
1.9	0	0.5	0.1
2.0	0	0.0	0.7
2.1	0	0.7	0.0
2.2	0	0.3	0.3
Total	355	314	294
>1V	30	64	49

Table 6-2
EOC 16 Projected Indications

Voltage Bin	Steam Generator			
	11	12	13	14
0.1	0.00	0.48	0.53	0.00
0.2	7.17	7.11	7.53	6.62
0.3	39.18	23.15	20.68	35.17
0.4	79.00	33.25	38.38	70.05
0.5	90.65	33.94	49.08	85.05
0.6	81.97	32.92	39.53	79.31
0.7	66.33	28.53	28.26	62.21
0.8	52.58	21.95	20.17	48.49
0.9	40.85	16.40	14.23	37.41
1.0	31.62	13.12	9.66	28.32
1.1	25.06	11.23	6.41	21.75
1.2	19.50	9.71	4.32	16.53
1.3	14.35	8.02	2.94	11.87
1.4	9.93	6.14	2.00	8.02
1.5	6.50	4.36	1.32	5.27
1.6	4.11	2.95	0.82	3.48
1.7	2.54	1.97	0.47	2.34
1.8	1.55	1.31	0.25	1.56
1.9	0.93	0.87	0.12	1.00
2.0	0.54	0.56	0.05	0.61
2.1	0.30	0.35	0.02	0.36
2.2	0.16	0.21	0.01	0.20
2.3	0.09	0.12	0.00	0.10
2.4	0.04	0.07	0.00	0.05
2.5	0.02	0.04	0.00	0.03
Total	575	259	247	526
>1V	86	48	19	73

Figure 6-1

SG 11 EOC 16

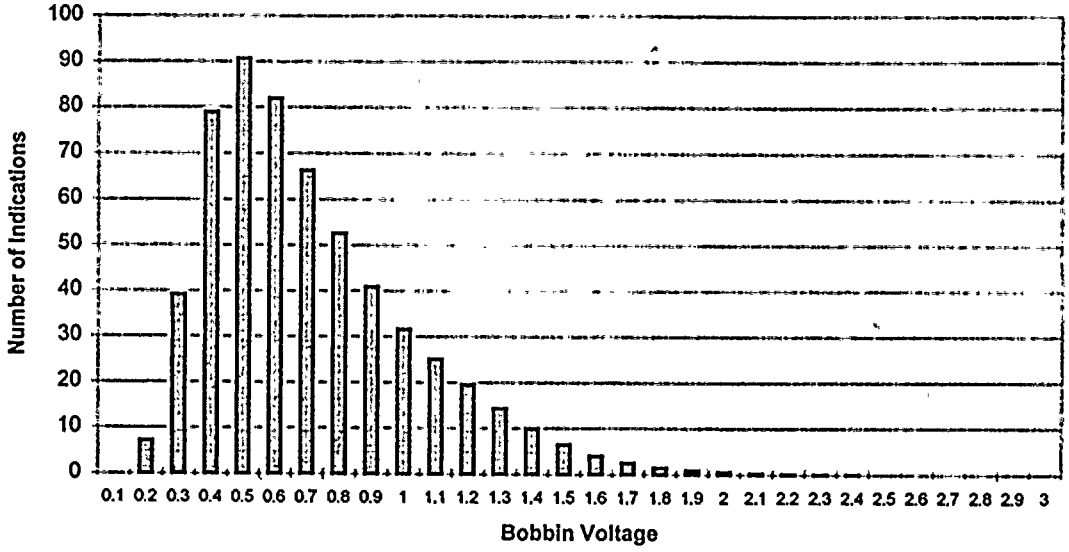


Figure 6-2

SG 12 EOC 16

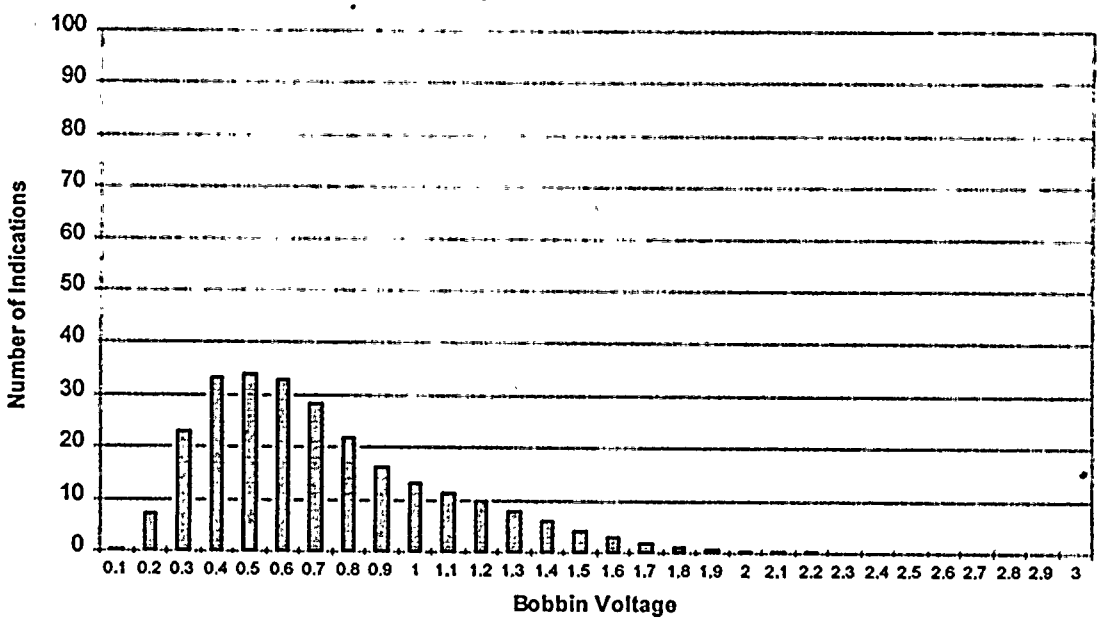


Figure 6-3

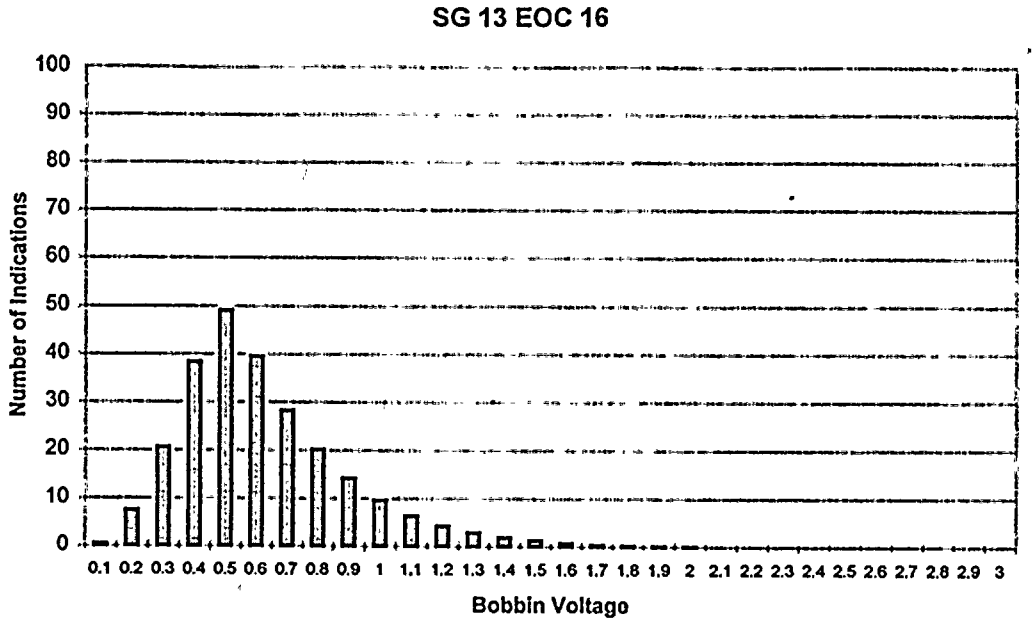
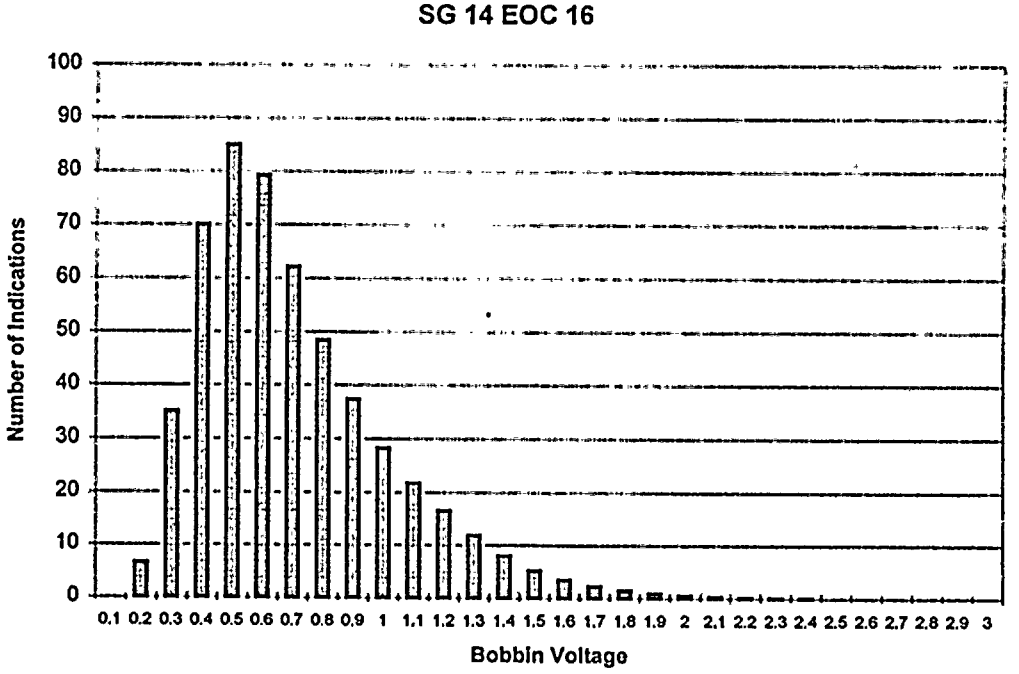


Figure 6-4



7.0 Tube Leak Rate and Tube Burst Probabilities

Correlation's 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 methodology used in the calculation of these parameters is consistent with NRC criteria and the guidelines of GL 95-05.

7.1 Predicted and Actual Leak Rate and Tube Burst Probability for EOC 15

Using the methodology previously described, analyses were performed to calculate EOC 15 MSLB tube leak rate and probability of burst for the actual bobbin voltage distribution at EOC 15 (with no growth projections 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 our Cook Unit 1 1995 Interim Plugging Criteria Report (December 1995), as shown on Table 7-1. Comparison of the EOC 15 actual to the corresponding predictions indicates that:

a) SG 11 was predicted to be the most limiting steam generator for cycle 15.

b) Based on actual ECT bobbin measurements at EOC 15, SG 11 has slightly more total (615 vs. 592) indications than SG 14.

c) The SG 11 tube leak rate (0.42 gpm) during a postulated MSLB at EOC 15 is lower than predicted for the required POD=0.6 for SG 14 (0.59 gpm). Even though leak rates are not significant at such low values. The MSLB leak rate of 0.42 gpm calculated from the actual EOC 15 voltage distribution is well below the Unit 1 allowable limit of less than 8.4 gpm.

d) The EOC 15 probability of burst prediction of 1.9×10^{-5} is conservative compared to the that based on actual ECT bobbin measurements (1.6×10^{-5}) and well below the reporting threshold of 1.0×10^{-2}.

e) The EOC 15 predictions based on POD=0.6 are higher when compared to the results based on EOC 15 actual conditions. This shows the conservatism that is built into the prediction models.

Table 7-1 includes the EOC 15 predicted values from the Cook Unit 1 1995 IPC 90 day report that used the current NRC approved data and exclusion criteria.

7.2 Leak Rate and Tube Burst Probability for EOC 16

Using the methodology previously described, calculations have been conducted to predict the performance of the limiting SG in Unit 1, with the BC voltage distributions predicted for EOC 16. Results of the EOC 16 predictions, summarized on Table 7-1, indicate that there are not major differences between the four SGs during the postulated MSLB conditions, since the tube leak rate and burst probability calculation results are so low. As shown on Table 7-1, the maximum difference in predicted EOC 16 MSLB tube leakage between the four SGs is 0.72 gpm, with the POD=0.6 as the most conservative. The corresponding range in number of single tube bursts, for all four steam generators varies from 1 to 5.1, in 500,000 Monte Carlo simulations and they are not as meaningful since the burst probabilities are so small.

The limiting SG for cycle 16 for Unit 1 is expected to be SG 11. With the NRC endorsed POD=0.6, the predicted EOC 16 MSLB leak rate for SG 11 is calculated as 0.96 gpm, whereas, SG 12 produces 0.47 gpm, SG 13 produces 0.24 gpm and SG 14 produces 0.86 gpm. The highest probability of burst occurs in both SG 11 and SG 14 at 1.2×10^{-5}. These results are well below the Cook Unit 1 allowable MSLB limit of 8.4 gpm and the reporting guideline for tube burst probability of 1.0×10^{-2}.

Table 7-1
D C Cook Unit 1 1997 RFO
Summary of MSLB Tube Leak Rate and Burst Probability

Steam Genarator	POD	Number of Indications	Max Volts[1]	POB	#tubes	MSLB Leak Rate gpm
EOC-15 Predicted						
11	0.6	344	2.4	1.9E-05	1	0.7
11	EPRI	317	2.3	1.9E-05	1	0.57
12	0.6	210	2.4	2.3E-05	1.7	0.5
12	EPRI	196	2.3	2.5E-05	2	0.39
13	0.6	154	2.1	2.9E-05	2.7	0.24
13	EPRI	145	2.0	2.5E-05	2	0.19
14	0.6	314	2.2	2.7E-05	2.3	0.59
14	EPRI	294	2.2	1.9E-05	1	0.47
EOC-15 Actual						
11	NA	371	1.8	1.6E-05	3	0.42
12	NA	169	1.9	9.7E-06	1	0.25
13	NA	160	1.7	6.0E-06	0	0.11
14	NA	358	1.8	1.6E-05	3	0.40
EOC-16 Predicted						
11	0.6	575	2.2	2.1E-05	5	0.96
11	EPRI	566	1.8	1.3E-05	2	0.76
12	0.6	259	2.3	1.2E-05	1.7	0.47
12	EPRI	253	1.9	1.3E-05	2	0.33
13	0.6	247	2.1	9.7E-06	1	0.24
13	EPRI	252	1.6	1.6E-05	3	0.18
14	0.6	526	2.5	2.1E-05	5.1	0.86
14	EPRI	521	1.8	1.5E-05	2.7	0.67

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

ATTACHMENT 3 TO AEP:NRC:1166AI

COOK STEAM GENERATORS U1R97

TUBE SAMPLE RESULTS

TUBE SAMPLE RESULTS

During U1R97, tube R8C19 was removed from steam generator 12 to below the fourth TSP. Non destructive testing has been completed, however, destructive examination of the tube specimen remains in progress.

Concerning the non destructive examination, macrophotography of the tubesheet and support plate regions has been performed as well as stereovisual examination in the support plate region. No unusual conditions or unexpected conditions were noted during these examinations. Helium leak testing has also been completed with no detectable leakage observed. Eddy current testing has been completed. While comparisons between field and laboratory results have not been finalized, general results indicate a favorable correlation.

Destructive examinations remain in progress. Leakrate testing, simulating normal and main steam line break pressures has been completed with no indication of through wall leakage. Burst testing has been completed with the second TSP intersection specimen bursting at 9356 psi. Due to mechanical and procedural test problems, the automatic burst pressure measurement on the first TSP intersection was not recorded. Visual observation of a mechanical pressure gauge noted the minimum burst pressure exceeded 7000 psi.

Examinations to date point to a combination of OD originated intergranular attack and axially oriented stress corrosion cracking randomly spaced around the tube circumference.

ATTACHMENT 4 TO AEP:NRC:1166AI

ACRONYM LISTING

ACRONYM LISTING

ARC	Alternate repair criteria
APC	Alternate plugging criteria
AVB	Anti-vibration bar
BC	Bobbin coil
BOC	Beginning of cycle
BRT	Bottom of roll transition
CPDF	Cumulative probability distribution function
CFR	Code of Federal Regulations
DLCO	Duquesne Light Company
DSI	Distorted support signal with possible indication
ECT	Eddy current testing
EFPD	Effective full power day
EFPY	Effective full power year
ECT	Eddy current testing
EOC	End-of-cycle
FTI	Framatome Technologies Incorporated
GL	Generic letter
GPD	Gallons per day
GPM	Gallons per minute
HEJ	Hybrid expansion joint
LRT	Lower roll transition
MSLB	Main steam line break
NDD	No detectable degradation
NDE	Non destructive examination
NOP	Normal operating pressure
NQI	Non-quantifiable indication
ODSCC	Outside diameter stress corrosion cracking
OEM	Original equipment manufacturer
POD	Probability of detection
PTI	Parent tube indication
PWSCC	Primary water stress corrosion cracking
RG	Regulatory guide
RPC	Rotating pancake coil
RR	Reroll
RRT	Reroll roll transition
RT	Roll transition
RTS	Return to service
SER	Safety evaluation report
SG	Steam generator
TEH	Tube end hot
TS	Tubesheet
T/S	Technical specifications
TSC	Tubesheet cold
TSH	Tubesheet hot
TSP	Tube support plate
TTS	Top-of-tubesheet
UEZ	Upper expansion zone
URT	Upper roll transition
UUE	Upper expansion
U1R9X	Unit 1 refueling outage in 199X