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BEAVER VALLEY UNIT - 1

CYCLE 17 VOLTAGE-BASED REPAIR CRITERIA 90-DAY REPORT

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1.0 Introduction

This report provides a summary of the Beaver Valley Unit-1 steam generator (SG) bobbin and RPC (+Pt) probe inspections at tube support plate (TSP) intersections together with postulated Steam Line Break (SLB) leak rate and tube burst probability analysis results. These results support continued implementation of the 2.0 volt voltage-based repair criteria for Cycle 17 as outlined in the NRC Generic Letter 95-05 (Reference 8-1). Information required by the Generic Letter is provided in this report including SLB leak rates and tube burst probabilities calculated using the end of cycle (EOC) conditions for the recently completed cycle (EOC-16 condition monitoring analysis) and projection of bobbin voltage distributions, leak rates and burst probabilities for the ongoing cycle (Cycle 17 operational assessment).

A total of 4185 axial outside diameter stress corrosion cracking (ODSCC) indications were identified by the bobbin probe. In addition, 67 support plate residual (SPR) indications, and three dent signals were confirmed as axial ODSCC by the plus point probe. Therefore a total of 4255 indications were included in the assessment of leakage and tube integrity.

Condition monitoring analysis at EOC-16 was carried out using the actual bobbin voltage distributions measured during the EOC-16 outage and the results compared with corresponding values from the projections performed based on the last (EOC-15) bobbin voltage data (presented in Reference 8-2). These evaluations utilized the Westinghouse generic Monte Carlo methodology presented in Reference 8-3.

Operational assessment analysis was performed to project leak rates and tube burst probabilities for postulated SLB conditions at the end of the ongoing cycle (Cycle 17) based on the 2.0 volt repair criteria. These analyses utilized bobbin voltage distributions measured during the recent (EOC-16) inspection and a limiting growth rate distribution from the last two inspections (EOC-15 and EOC-16 inspections). Leak and burst analyses for operational assessment were performed using a primary-to-secondary pressure differential of 2405 psi since credit can be taken for operability of pressurizer PORV during a SLB event (Reference 8-7).

2.0 Summary and Conclusions

A total of 4185 axial outside diameter stress corrosion cracking (ODSCC) indications were found by the bobbin probe during the EOC-16 inspection in all three SGs combined, of which 1746 were inspected with a RPC probe, and 1480 were confirmed as flaws. The plus point confirmation rate for bobbin DSIs is therefore 1480/1746 = 85%. The RPC confirmed indications included 518 indications above 1.0 volt. The largest number of bobbin indications, 1840 indications, was found in SG-A. A total of 20 indications were found above 2 volts in all SGs combined. All those indications were inspected with a RPC probe, and all but one indication were confirmed as flaws.

A total of 499 support plate residual (SPR) signals were inspected with the plus point probe. Of these 499 signals, 67 were confirmed as axial ODSCC indications by the plus point probe. The SPR confirmation rate is therefore 67/499 = 13%, much lower than the DSI confirmation rate. In addition three dent signals were confirmed as axial ODSCC. These 70 indications identified by plus point were included in the assessment of leakage and tube integrity. Each of these indications is assigned an equivalent bobbin DSI voltage based on a correlation with the indication plus point voltage. The maximum equivalent bobbin DSI voltage of these indications is 1.27 volts and the average equivalent bobbin DSI voltage of these indications is 0.85 volts.

No circumferential indications were identified by RPC inspection at TSP distorted signal indication (DSI) locations. One axial indication (R8 C80, 01H) was reported to extend outside the TSP by less than 0.1 inch. This indication was repaired and is discussed in Appendix B.

SLB leak rate and tube burst probability analyses were performed using the actual EOC-16 bobbin voltage distributions (condition monitoring analysis) as well as the projected EOC-17 bobbin voltage distributions (operational assessment). The actual number of indications detected during the EOC-16 inspection including the SPR and dent indications, for all SGs are below their corresponding projections based on the constant POD of 0.6. The EOC-16 measured voltages were bounded by the voltage distributions projected using POD = 0.6. SG-A was predicted to be the limiting SG at EOC-16 as it had a slightly higher projected SLB leak rate and burst probability than other 2 SGs, and it was also found to have the largest leak rate based on the measured EOC-16 voltages. The SLB leak rates from the condition monitoring analysis show significant margins relative to the corresponding operational assessment values based on a constant POD of 0.6; they are also well below the allowable limit of 14.5 gpm (room temperature). The corresponding condition monitoring tube burst probability values are also lower than the predicted values and well below the NRC reporting guideline of 10^{-2}.

The largest SLB leak rate in the condition monitoring analysis is calculated for SG-A, and its magnitude is 0.790 gpm, which is significantly less than the allowable SLB leakage limit of 14.5 gpm. All leak rate values quoted are equivalent volumetric rates at room

temperature. The limiting conditional tube burst probability from the condition monitoring analysis, 2.5×10^{-4} predicted for SG-A, is also well below the NRC reporting guideline of 10^{-2}. Thus, the condition monitoring results are well within the allowable limit/reporting guideline.

SLB leak rate and tube probability projections at the EOC-17 conditions were performed using the latest ARC database available (Addendum-6 update), which is documented in Reference 8-5. Since credit can be taken for the operability of the pressurizer PORV during a SLB event, leak and burst analyses for Cycle 17 operational assessment were performed using a primary-to-secondary pressure differential of 2405 psi. SG-A is again predicted to be the limiting SG. For Cycle 17 duration of 500 EFPD (Reference 8-10), the EOC-17 leak rate projected for SG-A using the NRC mandated constant POD of 0.6 is 1.91 gpm (room temperature), which is significantly less than the current licensing limit of 14.5 gpm. This leak rate projection utilized the current leak rate calculation methodology (Reference 8-4) wherein a test is made during each SG simulation to determine whether or not a correlation exists between leak rate and bobbin voltage. A regression correlation is applied for (1-p) fraction of the SG simulations, where "p" is the p-value for the leak rate correlation slope parameter. In the remaining simulations, leak rate is assumed independent of bobbin voltage and is determined using the mean and standard deviation of the leak data. The limiting EOC-17 burst probability is also calculated for SG-A; its magnitude is 8.5×10^{-4}, an order of magnitude below the NRC reporting guideline of 10^{-2}.

3.0 EOC-16 Inspection Results and Voltage Growth Rates

3.1 EOC-16 Inspection Results

According to the guidance provided by the NRC Generic Letter 95-05, the EOC-16 inspection of the Beaver Valley Unit-1 SGs consisted of a complete, 100% eddy current (EC) bobbin probe full length examination of the tube bundles in all three SGs. RPC examination was also performed for all indications with amplitude 2 volts and above and many indications in each SG with amplitude below 2 volts. Among the indications above 2 volts, all but one were confirmed as flaws, and the tube containing them were removed from service. Only a total of 11 ODSCC indications were found on the cold leg side at the TSPs from all 3 SGs combined. There were no circumferential indications at TSPs. One axial indication (R8 C80, 01H) was reported to extend outside the TSP by less than 0.1 inch. This indication was repaired and is discussed in Appendix B.

A summary of the EC indications for all three SGs is shown on Table 3-1, which tabulates the number of field bobbin indications, including the equivalent bobbin voltage for the SPR and dent indications, and the number of indications removed from service due to tube repairs. All confirmed SPR and dent indications were repaired. The number of indications that remain active for Cycle 17 operation is the difference between the observed and the ones removed from service. No tubes were deplugged in the current inspection with the intent of returning them to service after inspection in accordance with the alternate repair criteria (ARC).

Overall, the combined data for all three SGs of Beaver Valley Unit-1 show the following:

- Out of a total of 4185 TSP bobbin indications identified during the inspection, a total of 1746 were RPC inspected.
- Of the 1746 RPC inspected, 1480 were confirmed as flaws.
- 67 SPR indications were confirmed as axial ODSCC by plus point probe
- 3 dent indications were confirmed as axial ODSCC by plus point
- Including the SPR and dent indications with equivalent bobbin voltages gives a total of 4255 indications.
- A total of 3983 indications were returned to service for Cycle 17 operation.

A review of Table 3-1 indicates that more indications (a quantity of 1719, with 369 indications above 1.0 volt) were returned to service in SG-A than the other SGs; thereby it is expected to be the limiting SG at EOC-17.

Figure 3-1 shows the bobbin voltage distribution determined from the EOC-16 EC inspection. Figure 3-2 shows the population distribution of those EOC-16 indications removed from service due to tube repairs. The large number in the 0.9 volt bin for SG A is due to the SPR indications, most of which were in the 0.8 to 0.9 equivalent bobbin volt range. Figure 3-3 shows the distribution for indications returned to service for Cycle 17 operation. Of the 272 indications removed from service, 19 indications were repaired due to exceeding the 2 volt criterion for ODSCC at TSPs and 70 were repaired due to confirmed ODSCC at SPR and dent indications. All other repaired indications are in tubes plugged for degradation mechanisms other than ODSCC at TSPs.

The distribution of EOC-16 indications as a function of support plate location is summarized in Table 3-2 and plotted in Figure 3-4. The number of indications included the SPR and dent indications, but the voltage values are for bobbin voltage only. The data show a strong predisposition of ODSCC to occur in the first few hot leg TSPs (3886 out of 4255 indications occurred at the hot leg intersections in the first three TSPs), although the mechanism extended to higher TSPs. Only a total of 11 indications were detected on the cold leg side in all 3 SGs combined. This distribution indicates the predominant temperature dependence of ODSCC at Beaver Valley Unit-1, consistent with the data from the previous inspections at Beaver Valley Unit-1 as well as other plants.

3.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at the end of Cycle 17 operation, voltage growth rates were developed from the EOC-16 inspection data and a reevaluation of the EOC-15 inspection bobbin EC signals for the same indications. The SPR and dent indications, because there is no bobbin volt history are excluded from the development of the voltage growth rates. Table 3-3 shows the cumulative probability distribution for growth rate in each Beaver Valley Unit-1 steam generator during Cycle 16 (527.7 EFPD, Reference 8-10) on an EFPY basis, along with the bounding SG A Cycle 15 growth rate distributions which bounded the other SG distributions in Cycle 15. The curve labeled "Composite" in Figure 3-5 represents averaged composite growth data from all three SGs.

Average growth rates for each SG during Cycle 16 are summarized in Table 3-4, and all three SGs show comparable average growth rates, as in the last cycle. The average growth rates over the entire voltage range vary between 1.0 % and 5.0% (of the BOC voltage) per EFPY, with an overall average of 3.46% per EFPY. SG-C had a slightly higher growth than the other two SGs. Table 3-5 provides a comparison of the average growth data for the last four operating cycles. The Cycle 16 growth rates are less than the Cycle 15 growth rates, which in turn is less than the Cycle 14 growth rates. This growth rate reduction may be a residual effect of the chemical cleaning crevice cleaning process applied at the 1R14 outage.

The bobbin voltage growth distributions for the last two cycles in the form of cumulative

probability distribution functions (CPDF) are shown in Table 3-3, and the same data is presented in a graphical form on Figure 3-5. The growth data are presented on an EFPY basis to account for the difference in the length of the two operating periods. Since the SG A Cycle 15 growth distribution in Figure 3-5 lies to the right of the Cycle 16 distribution for all SGs and has a slightly higher peak growth, it is considered more limiting. Therefore, the Cycle 17 operational assessment analysis was carried out using the SG A Cycle 15 growth distribution.

Table 3-6 lists the indications with Cycle 16 growth greater than 0.4 volts. This confirms that Cycle 16 had only modest growth. Some plants have experienced growth rates that demonstrated a potential dependency on the BOC voltages of previously identified indications. Large growths were observed primarily in indications with a BOC voltage over 1.5 volts. To determine if Beaver Valley Unit-1 exhibited a similar trend, the growth rate data for Cycle 16 was plotted against BOC voltage, and the resulting plot is shown in Figure 3-6. Although there is one indication with a higher growth than the rest of the population (0.94 volts), its BOC voltage is well below 1.0 Volt. The Cycle 16 growth data do not show any trend to increase with the BOC voltage. Therefore, growth can be assumed independent of voltage in the Monte Carlo analysis for the operational assessment.

3.3 Probe Wear Criteria

An alternate probe wear criteria approved by the NRC (Reference 8-6) was applied during the EOC-16 inspection. When a probe does not pass the 15% wear limit, this alternate criteria requires that only tubes with indications above 75% of the repair limit inspected since the last successful probe wear check be reinspected with a good probe. As the repair limit for Beaver Valley Unit-1 is 2 volts, all tubes containing indications for which the worn probe voltage is above 1.5 volts are to be inspected with a new probe. A total of 26 indications with a bobbin voltage above 1.5 volts were found in the calibration groups that failed probe wear check, and the tubes containing those indications were reinspected with a new probe. Four additional indications < 1.5 V were reported on these tubes and also were reinspected with a new probe. One indication had its voltage increase above the repair limit when reinspected with a good probe (R18C77 02H in SG-A). It was inspected with a RPC probe and confirmed as a flaw. The tube containing that flaw was repaired. For indications with a worn probe voltage above 1.5 volts, the average difference between the worn and new probe voltages is -0.12 V and suggests that in general, the worn probe voltage exceeds the new probe voltage. Figure 3-7 shows plots of the worn probe voltages plotted against the new probe voltages for all three SGs. The data in Figure 3-7 show a consistent relationship between the two voltages, with worn probe voltages being generally higher.

Also shown in Figure 3-7 as a solid line is a linear regression for the data, dotted lines representing tolerance limits that bound 90% of the population at 95% confidence, and a chained line representing ±25% band for the new probe voltages. The mean regression

line has a slope slightly above 45° indicating that, on the average, worn probe voltages are slightly higher than the new probe voltages. The solid vertical line at 2 V on the x-axis shows the 1.5V threshold for retesting with a new probe is bounded by the lower 90%/95% tolerance limit. In the Beaver Valley-1 EOC-16 inspection, there are no occurrences for which a worn probe was less than 1.5 volts and the new probe voltage exceeded the plugging limit, i.e., no pluggable tubes were missed due to probe wear considerations. Among the indications requiring retesting (worn probe volts > 1.5 volts), only 1 indication falls outside the 90%/95% tolerance limit bands. However, the worn probe voltage for this indication is higher than the corresponding new probe voltage, i.e., the worn probe voltages are conservative. Therefore the data for these indications are acceptable.

Overall, it is concluded that the criteria to retest tubes with worn probe voltages above 75% of the repair limit is adequate. The alternate probe wear criteria used in the EOC-16 inspection is consistent with the NRC guidance provided in Reference 8-6.

As required by Reference 8-6, the number of new indications detected in the present inspection in tubes that were inspected with a worn probe in the last inspection was also determined. Out of approximately 365 new indications found in the current inspection, only 1 is in a tube inspected with a worn probe in the last inspection, which indicates that tubes inspected with worn probes during the last inspection do not contain disproportionately larger number of new indications. Thus, the requirements specified in Reference 8-6 for applying the alternate probe wear criteria are met.

3.4 NDE Uncertainties

The NDE uncertainties applied for the Cycle 16 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those previously reported in the Beaver Valley Unit-1 voltage-based repair criteria report of Reference 8-2 and NRC Generic Letter 95-05 (Reference 8-1). The probe wear uncertainty has a standard deviation of 7.0 % about a mean of zero and has a cutoff at 15% based on implementation of the probe wear standard. If the random sample of probe wear selected during the Monte Carlo simulations exceed 15%, sampling of the probe wear distribution is continued until a value less than 15% is picked. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses for SLB leak rates and tube burst probabilities based on the EOC-16 actual voltage distributions as well as for the EOC-17 projections. In the EOC-17 projection analysis, NDE uncertainty adjustment is applied to the BOC voltage before growth is added to obtain EOC voltage.

3.5 Probability of Prior Cycle Detection (POPCD)

The inspection results at EOC-16 permit an evaluation of the probability of detection at the previous (EOC-15) inspection. The POPCD evaluation has been carried out for the

previous 5 inspections at Beaver Valley Unit-1. In all the previous analyses the probability of burst and leakage assessments using POPCD showed significantly more margin than the assessments using the NRC mandated POD of 0.6. These assessments demonstrated the conservatism inherent in the use of the POD of 0.6. The indication voltage distribution of the current inspection results (EOC-16), however, is low thereby resulting in predicted probability of burst and leakage using the POD of 0.6 to be well below the reporting criteria. Therefore since the measured voltage growth was small at the current inspection, and Cycle 17 is the last operating cycle before SG replacement, the value of the POPCD evaluation is diminished and the NRC required POD of 0.6 can be successfully used for the operational assessment analysis.

3.6 Assessment of RPC Confirmation Rates

Table 3-7 shows the number of indications that were tested with RPC and the number that confirmed axial ODSCC and the number that showed no degradation. The NRC SER for Beaver Valley-1 (Reference 8-8) allows for consideration of only a fraction of RPC NDD indications from current inspection in establishing BOC voltage distribution for the next cycle. The fractional value applicable is the largest RPC confirmation rate for prior cycle RPC NDD indications found during the last two outages, but it may not be less than 0.7. However, all EOC-16 RPC NDD indications were included in the Cycle 17 operational assessment.

Table 3-1
Beaver Valley Unit 1 October 2004 Outage
Summary of Inspection and Repair for Tubes in Service During Cycle 16

Voltage Bin	Steam Generator A			Steam Generator B		
	In Service Cycle 16		Return	In Service Cycle 16		Return
	Field Bobbin Indications	Indications Repaired	For Cycle 17	Field Bobbin Indications	Indications Repaired	For Cycle 17
0.1	0	0	0	0	0	0
0.2	13	1	12	12	0	12
0.3	60	2	58	65	1	64
0.4	144	8	136	116	2	114
0.5	170	11	159	166	2	164
0.6	252	12	240	188	4	184
0.7	222	13	209	174	1	173
0.8	221	18	203	166	6	160
0.9	245	40	205	123	3	120
1	146	18	128	86	2	84
1.1	107	16	91	72	2	70
1.2	80	4	76	40	1	39
1.3	68	4	64	31	3	28
1.4	34	3	31	24	4	20
1.5	25	3	22	20	0	20
1.6	36	4	32	13	1	12
1.7	23	1	22	6		6
1.8	12	0	12	4		4
1.9	11	1	10	6		6
2	9	1	8	2		2
2.1	5	4	1			0
2.2	1	1	0			0
2.3	2	2	0			0
2.4	1	1	0			0
2.5			0			0
			0			0
			0			0
Total	1887	168	1719.0	1314	32	1282.0
> 1V	414	45	369.0	218	11	207.0
> 2V	9	8	1.0	0	0	0.0

Voltage Bin	Steam Generator C			Composite of All SGs		
	In Service Cycle 16		Return	In Service Cycle 16		Return
	Field Bobbin Indications	Indications Repaired	For Cycle 17	Field Bobbin Indications	Indications Repaired	For Cycle 17
0.1	0	0	0	0	0	0
0.2	12	0	12	37	1	36
0.3	57	0	57	182	3	179
0.4	84	3	81	344	13	331
0.5	102	3	99	438	16	422
0.6	137	6	131	577	22	555
0.7	127	7	120	523	21	502
0.8	110	10	100	497	34	463
0.9	116	12	104	484	55	429
1	76	7	69	308	27	281
1.1	42	1	41	221	19	202
1.2	35	1	34	155	6	149
1.3	37	4	33	136	11	125
1.4	32	2	30	90	9	81
1.5	18	2	16	63	5	58
1.6	22	1	21	71	6	65
1.7	13	1	12	42	2	40
1.8	8	0	8	24	0	24
1.9	8	0	8	25	1	24
2	7	1	6	18	2	16
2.1	5	5	0	10	9	1
2.2	2	2	0	3	3	0
2.3	4	4	0	6	6	0
2.4			0	1	1	0
2.5			0	0	0	0
			0	0	0	0
			0	0	0	0
Total	1054	72	982.0	4255	272	3983.0
> 1V	233	24	209.0	865	80	785.0
> 2V	11	11	0.0	20	19	1.0

Table 3-2
Beaver Valley Unit 1 October 2004 Outage
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 16

Tube Support Plate	Steam Generator A					Steam Generator B				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
01H	895	2.32	0.85	0.94	0.05	632	1.99	0.77	0.34	0
02H	624	2.08	0.77	0.4	0.04	393	1.61	0.73	0.27	0.01
03H	214	1.6	0.69	0.47	0.05	155	1.75	0.62	0.43	0.03
04H	83	1.41	0.63	0.31	0.03	86	1.44	0.6	0.26	0.03
05H	34	1.04	0.56	0.3	0.05	28	1.16	0.5	0.13	0.03
06H	10	1.08	0.5	0.11	0.03	14	0.9	0.41	0.16	0.04
07H	20	0.99	0.45	0.22	0.04	4	0.38	0.33	0.02	-0.01
07C	6	0.46	0.34	0.08	0.02	2	0.24	0.22	-0.04	-0.05
06C	1	0.47	0.47	0.13	0.13					
04C										
02C										
Total	1887					1314				

Tube Support Plate	Steam Generator C					Composite of All SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
01H	496	2.23	0.9	0.72	0.06	2023	2.32	0.84	0.94	0.04
02H	353	2.29	0.74	0.41	0.05	1370	2.29	0.75	0.41	0.03
03H	124	1.81	0.66	0.3	0.04	493	1.81	0.66	0.47	0.04
04H	36	1.66	0.61	0.21	0.04	205	1.66	0.61	0.31	0.03
05H	24	0.85	0.43	0.15	0.02	86	1.16	0.50	0.3	0.04
06H	18	0.97	0.45	0.28	0.07	42	1.08	0.45	0.28	0.05
07H	1	0.47	0.47	0.08	0.08	25	0.99	0.43	0.22	0.03
07C	0					8	0.47	0.31	0.08	0.00
06C	0					1	0.47	0.47	0.13	0.13
04C	1	0.62	0.62	0.16	0.16	1	0.62	0.62	0.16	0.16
02C	1	0.38	0.38	0.03	0.03	1	0.38	0.38	0.03	0.03
Total	1054					4255				

Table 3-3
Beaver Valley Unit 1 October 2004 Outage
Signal Growth Statistics for Cycle 16 Bobbin Indications on an EFPY Basis

	Steam Generator A			Steam Generator B			Steam Generator C			Composite		
Delta	Cycle 15	Cycle 16		Cycle 15	Cycle 16		Cycle 15	Cycle 16		Cycle 15	Cycle 16	
Volts	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
-0.6	0	0	0.000	0.001	0	0.000	0	0	0.000	0	0	0.000
-0.5	0.001	0	0.000	0.001	0	0.000	0	0	0.000	0.001	0	0.000
-0.4	0.001	0	0.000	0.001	1	0.001	0	1	0.001	0.001	2	0.000
-0.3	0.001	0	0.000	0.001	0	0.001	0.003	0	0.001	0.001	0	0.000
-0.2	0.01	1	0.001	0.006	1	0.002	0.006	0	0.001	0.008	2	0.001
-0.1	0.04	16	0.009	0.05	47	0.037	0.059	9	0.010	0.048	72	0.018
0	0.307	487	0.274	0.359	550	0.458	0.382	276	0.276	0.341	1313	0.332
0.1	0.76	1159	0.904	0.827	649	0.954	0.804	621	0.875	0.792	2429	0.912
0.2	0.923	150	0.985	0.963	57	0.998	0.939	116	0.986	0.94	323	0.989
0.3	0.975	24	0.998	0.984	3	1.000	0.986	12	0.998	0.98	39	0.999
0.4	0.998	2	0.999	0.992	0	1.000	0.99	1	0.999	0.99	3	1.000
0.5	0.994	0	0.999	0.996	0	1.000	0.995	1	1.000	0.995	1	1.000
0.6	0.998	0	0.999	0.998	0	1.000	0.999	0	1.000	0.998	0	1.000
0.7	0.998	1	1.000	0.999	0	1.000	0.999	0	1.000	0.999	1	1.000
0.8	0.999	0	1.000	1	0	1.000	0.999	0	1.000	0.999	0	1.000
0.9	0.999						0.999			0.999		
1	0.999						1			0.9997		
1.1	0.999									0.9997		
2.5	1									1		
Total		1840			1308			1037			4185	

Table 3-4
Beaver Valley Unit 1 October 2004 Outage
Average Voltage Growth During Cycle 16

Voltage Range	Number of Bobbin Indications	Average Voltage BOC	Average voltage growth		Percent Growth	
			Cycle	EFPY	Cycle	EFPY
Composite						
Entire voltage range	4185	0.729	0.036	0.025	5.00%	3.46%
Vboc<0.75 Volts	2466	0.501	0.038	0.026	7.63%	5.28%
Vboc >=0.75 Volts	1719	1.056	0.034	0.024	3.22%	2.23%
SGA						
Entire voltage range	1840	0.743	0.046	0.032	6.19%	4.29%
Vboc<0.75 Volts	1051	0.511	0.044	0.030	8.61%	5.96%
Vboc >=0.75 Volts	789	1.051	0.049	0.034	4.66%	3.23%
SGB						
Entire voltage range	1308	0.706	0.010	0.007	1.42%	0.98%
Vboc<0.75 Volts	803	0.501	0.023	0.016	4.59%	3.18%
Vboc >=0.75 Volts	505	1.032	-0.011	-0.008	-1.07%	-0.74%
SGC						
Entire voltage range	1037	0.735	0.053	0.037	7.20%	4.98%
Vboc<0.75 Volts	612	0.485	0.048	0.034	9.98%	6.91%
Vboc >=0.75 Volts	425	1.093	0.060	0.041	5.44%	3.77%

Table 3-5
History of Average Voltage Growth
Composite of all Steam Generator Data

Bobbin Voltage Range	Number of Bobbin Indications	Average Voltage BOC	Average voltage growth		Percent Growth	
			Cycle	EFPY	Cycle	EFPY
Cycle 16 (527.7 EFPD)						
Entire voltage range	4185	0.729	0.036	0.025	5.00%	3.46%
Vboc<0.75 Volts	2466	0.501	0.038	0.026	7.63%	5.28%
Vboc >=0.75 Volts	1719	1.056	0.034	0.024	3.22%	2.23%
Cycle 15 (485.3 EFPD)						
Entire voltage range	3977	.71	.059	.044	8.2%	6.2%
Vboc<0.75 Volts	2449	.49	.065	.049	13.2%	9.9%
Vboc >=0.75 Volts	1528	1.06	.049	.037	4.6%	3.4%
Cycle 14 (490 EFPD)						
Entire voltage range	3533	.67	.076	.057	11.4%	8.5%
Vboc<0.75 Volts	2371	.48	.080	.060	16.6%	12.4%
Vboc >=0.75 Volts	1162	1.05	.068	.050	6.4%	4.8%
Cycle 13 (500 EFPD)						
Entire voltage range	3024	.56	.138	.101	24.8%	18.1%
Vboc<0.75 Volts	2371	.43	.127	.093	29.6%	21.7%
Vboc >=0.75 Volts	653	1.03	.180	.131	17.5%	12.8%

Table 3-6
Beaver Valley Unit 1 October 2004 Outage
Summary of Largest Voltage Growth Rates During Cycle 16

Location				Bobbin Voltage		
SG	Row	Column	Elevation	EOC	BOC	Growth
A	28	27	01H	1.74	0.8	0.94
C	10	55	01H	1.59	0.87	0.72
A	37	50	01H	1	0.46	0.54
C	39	32	01H	2.16	1.66	0.5
A	36	66	03H	1.59	1.12	0.47
A	14	63	01H	1.19	0.76	0.43
B	33	56	03H	0.89	0.46	0.43
A	16	18	01H	1.18	0.76	0.42
A	6	44	01H	1.12	0.7	0.42
A	4	5	01H	1.55	1.14	0.41
A	11	13	01H	0.69	0.28	0.41
C	15	63	02H	1.53	1.12	0.41
A	18	77	02H	2.02	1.62	0.4
C	27	18	01H	2.22	1.82	0.4

Table 3-7
Beaver Valley Unit 1 October 2004 Outage
Summary of RPC Confirmation at EOC 16
All Steam Generators

Voltage Bins	Total Number of Bobbin Indications	Bobbin Indications Confirmed by RPC	Bobbin Indications Not Confirmed by RPC
0.1	0	0	0
0.2	37	8	7
0.3	182	33	28
0.4	344	80	41
0.5	438	145	39
0.6	577	176	35
0.7	523	172	37
0.8	478	130	26
0.9	447	139	18
1.0	300	79	9
1.1	217	57	4
1.2	154	62	6
1.3	135	80	5
1.4	90	81	4
1.5	63	57	3
1.6	71	63	1
1.7	42	36	2
1.8	24	24	0
1.9	25	23	0
2.0	18	16	0
2.1	10	9	1
2.2	3	3	0
2.3	6	6	0
2.4	1	1	0
Total	4185	1480	266

Figure 3-1
Beaver Valley Unit 1
Bobbin Voltage Distributions at EOC-16 for Tubes in Service During Cycle 16

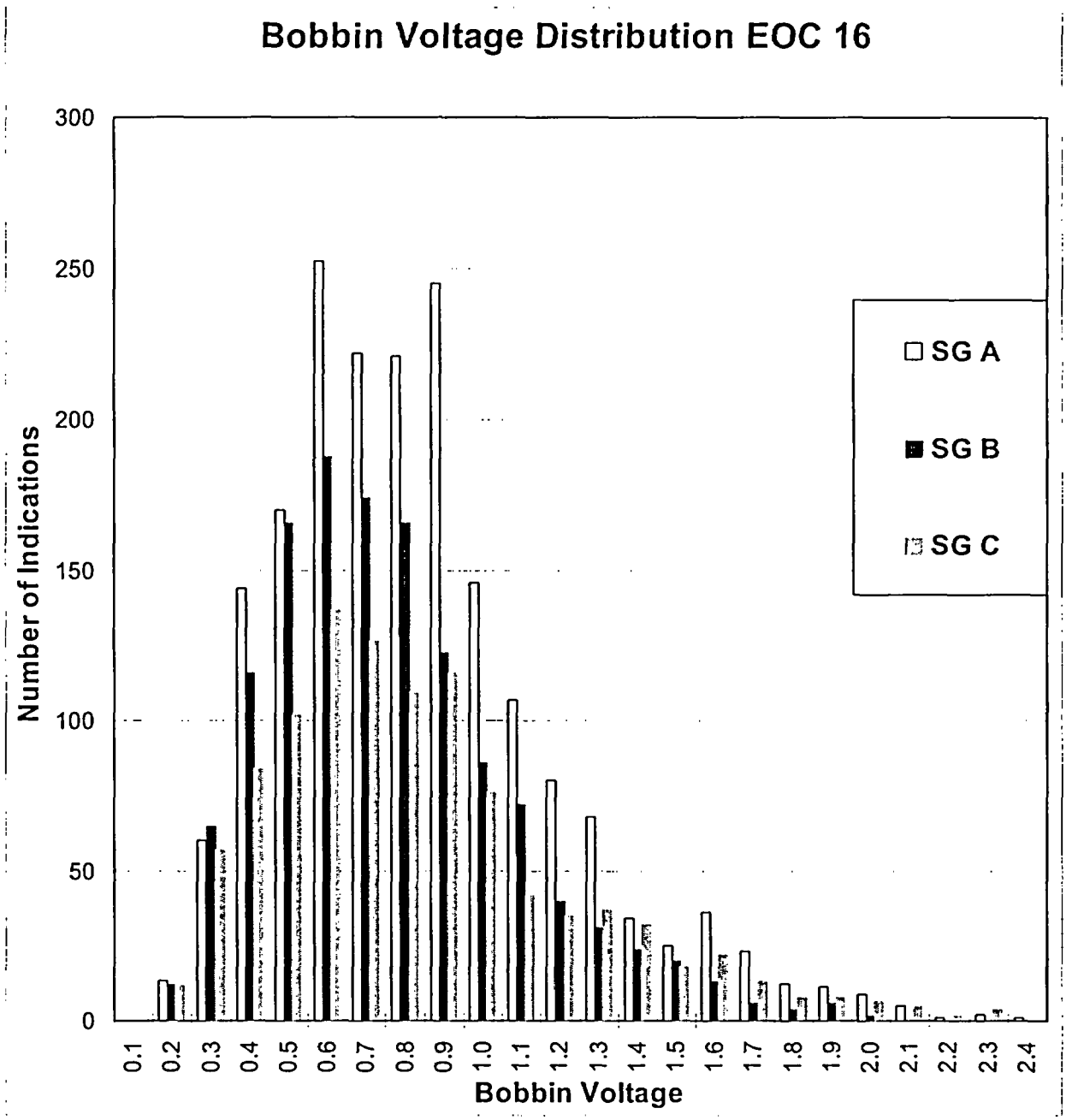


Figure 3-2
Beaver Valley Unit 1
Bobbin Voltage Distribution of Indications Repaired at EOC-16

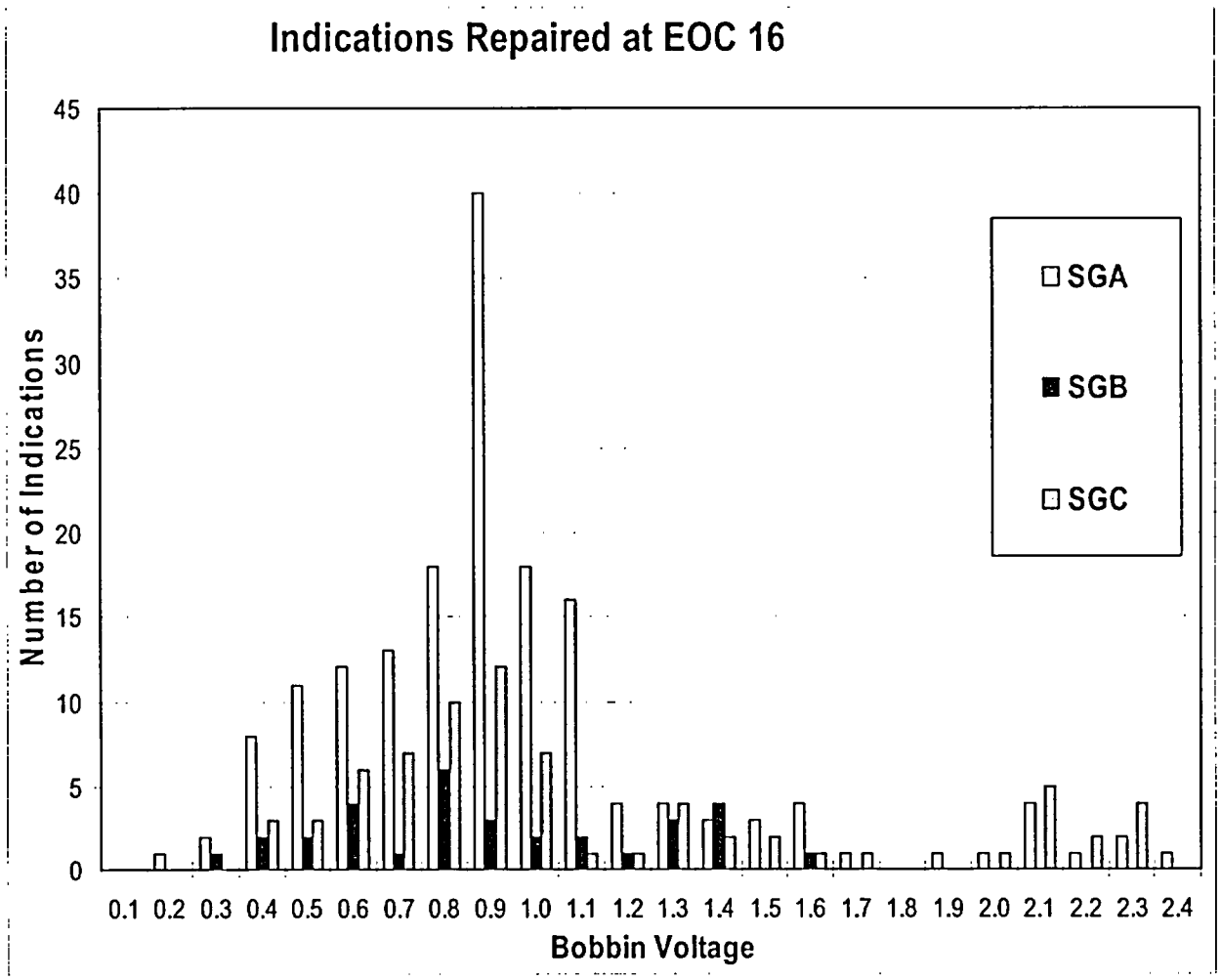


Figure 3-3
Beaver Valley Unit 1
Bobbin Voltage Distribution of Indications Returned to Service for Cycle 17

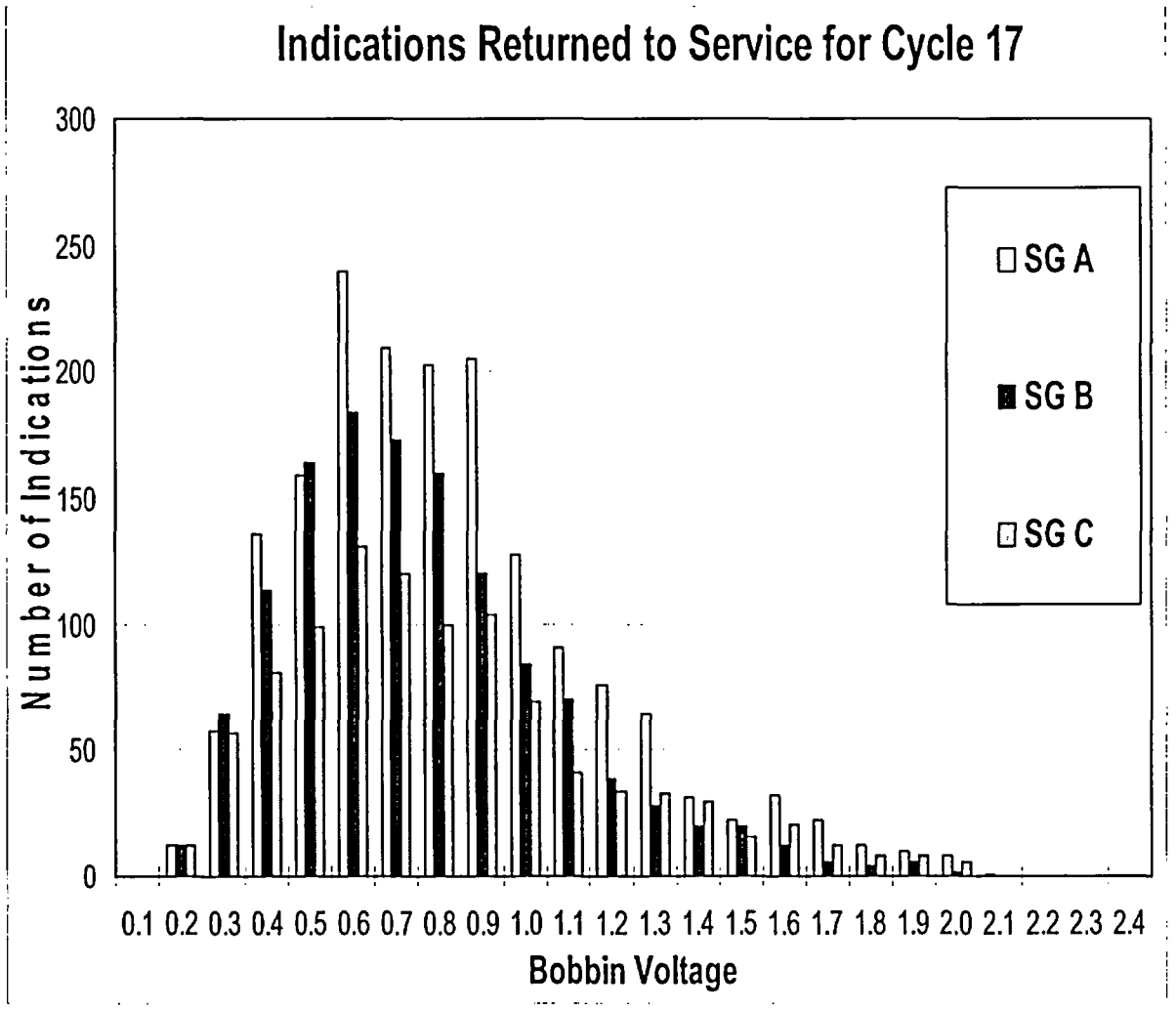


Figure 3-4
Beaver Valley Unit 1
Bobbin Voltage Distribution of Indications at Supports at EOC-16

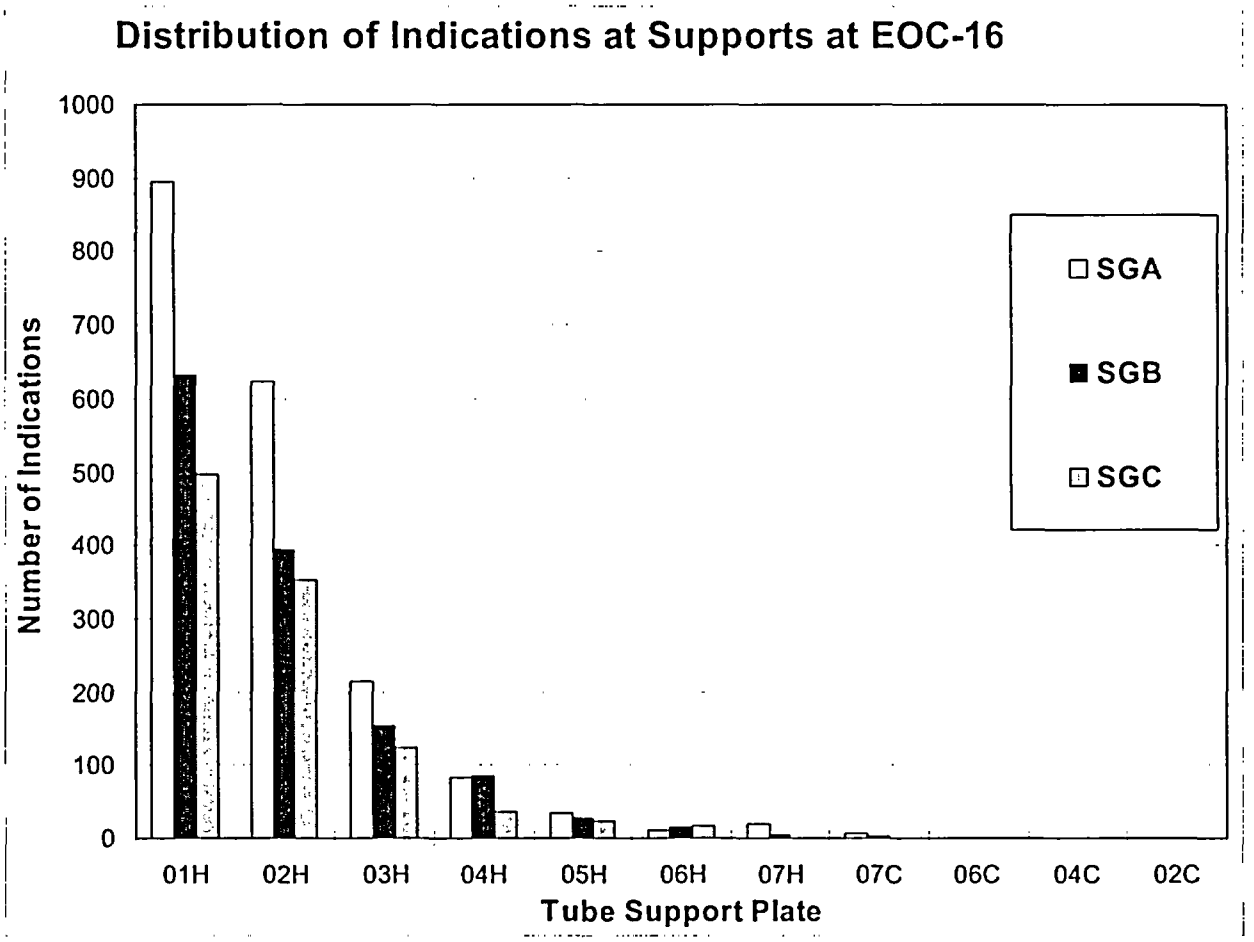


Figure 3-5
Beaver Valley Unit 1
Cumulative Distributions for Voltage Growth on an EFPY Basis, Cycle 16

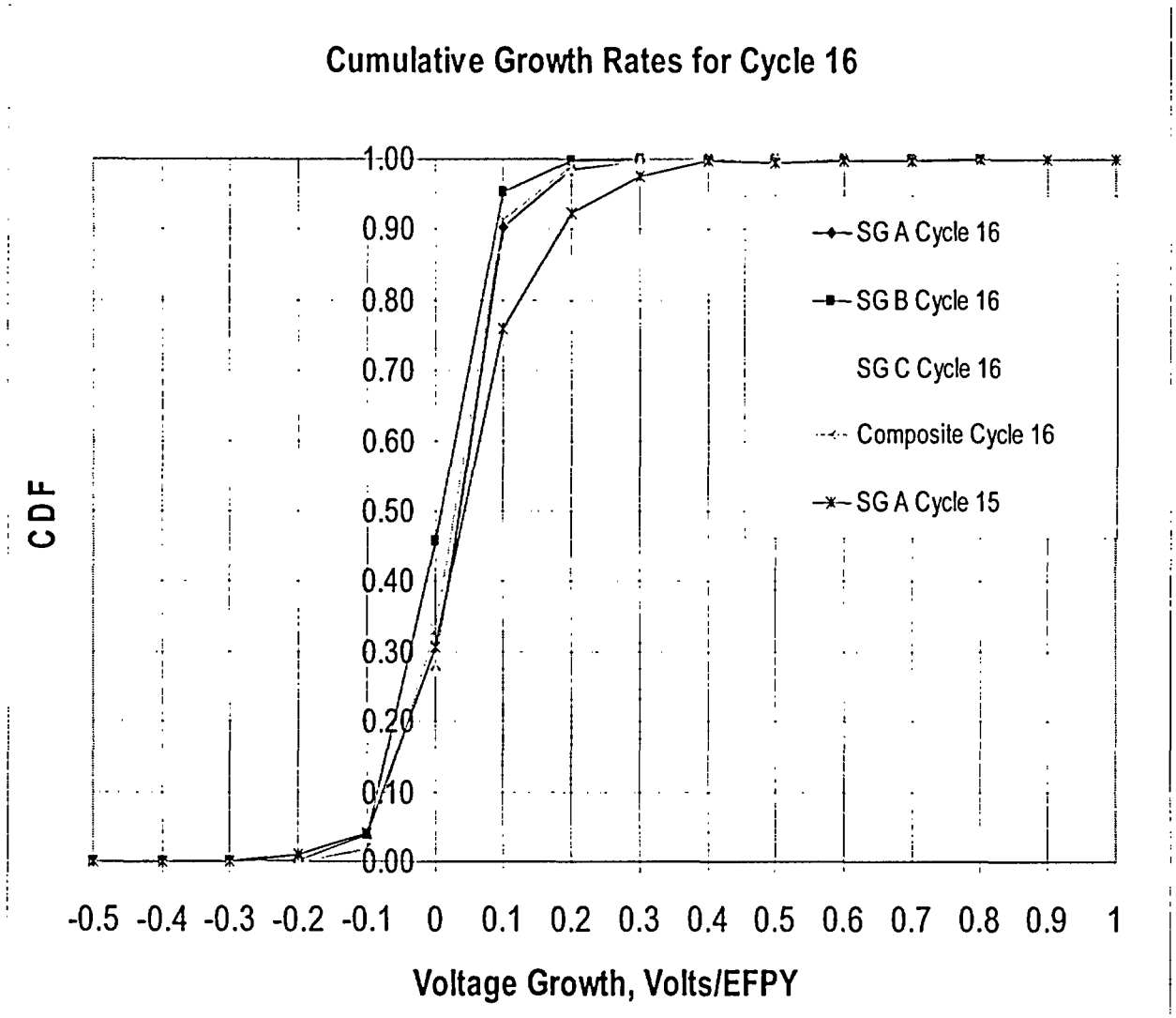


Figure 3-6
Beaver Valley Unit 1
Voltage Growth During Cycle 16 vs BOC Voltage

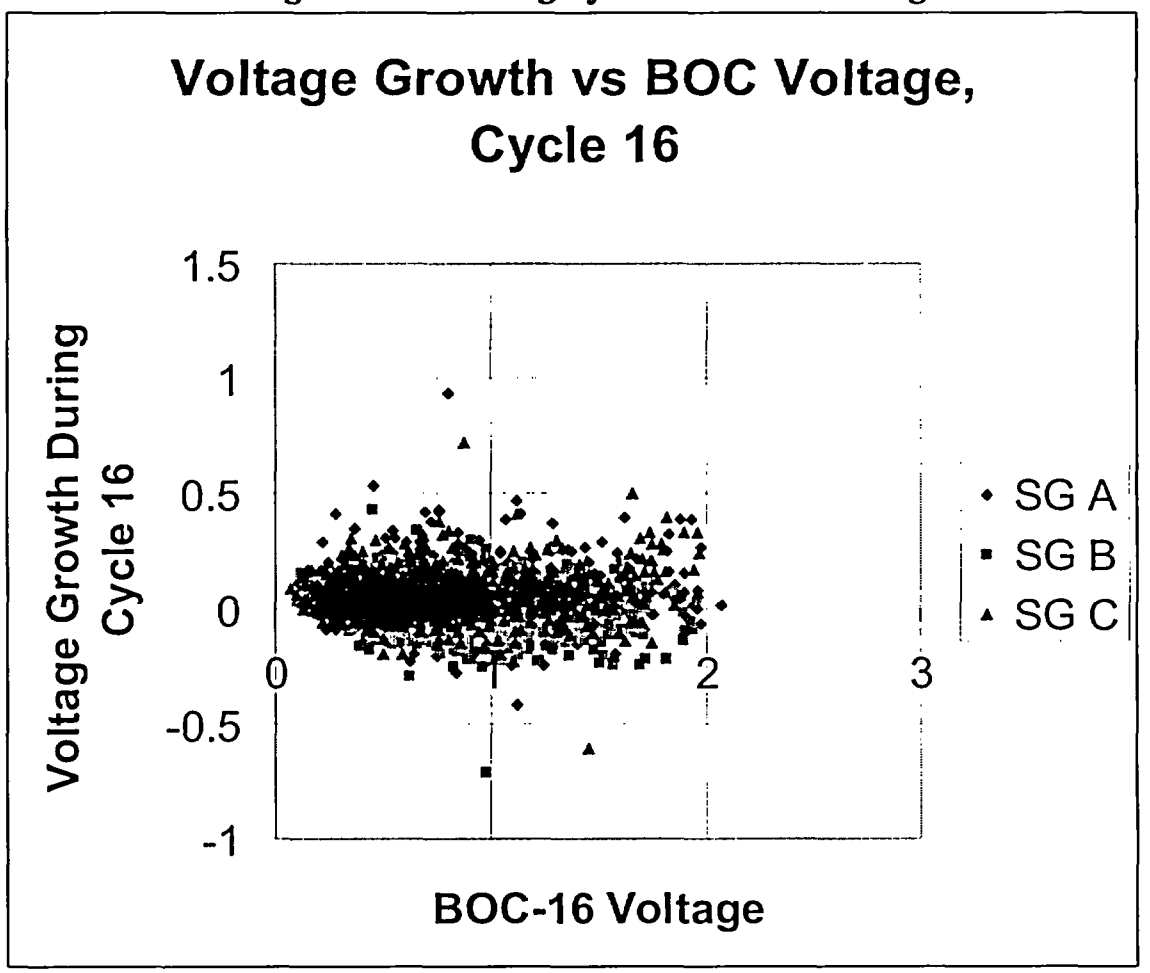
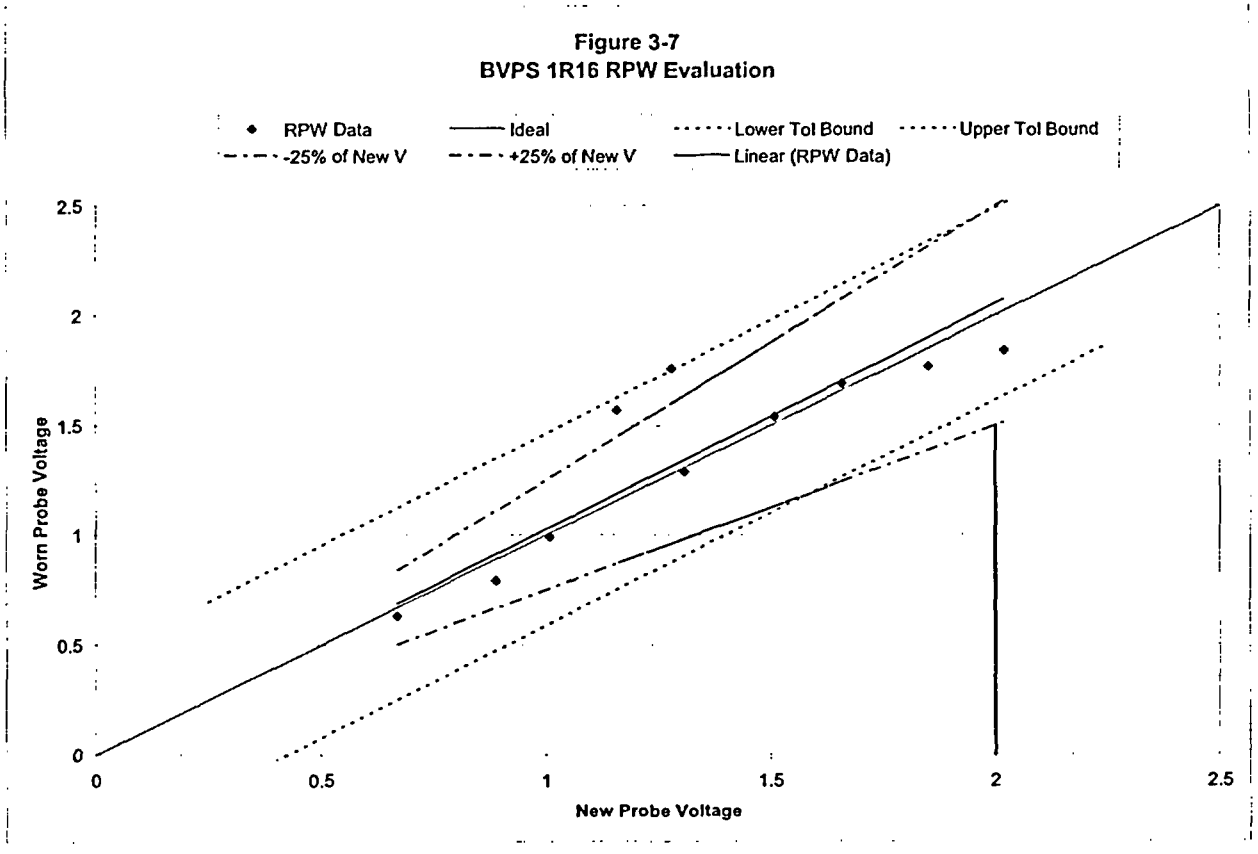


Figure 3-7
Beaver Valley Unit 1
Probe Wear Assessment at EOC-16



4.0 Database Applied for Leak and Burst Correlations

Leak and burst correlations based the latest update to the ARC database documented in Reference 8-5 (Addendum-6 update) were utilized to perform leak and burst calculations for both EOC-16 condition monitoring and Cycle 17 operational assessment.

The following are the correlations for burst pressure, probability of leakage and leak rate used in the reference analyses for this report (Reference 8-5).

Burst Pressure (*ksi*) = $7.4801 - 2.4002 \times \log(volts)$

Probability of Leak = $\dfrac{1}{1 + e^{-(-5.0407 + 7.5434 \times \log(volts))}}$

Leak Rate (*l/hr*) = $10^{(-0.5348 + 0.9699 \times \log(volts))}$ at $\Delta P = 2405$ psi

The Cycle 16 operational assessment was carried out using Addendum 5 ARC database. Therefore that database discussed in Reference 8-2 will also be used for comparison to the condition monitoring results at EOC-16.

The upper voltage repair limit applied at the EOC-16 inspection was developed using the database presented in Reference 8-5, which is the latest database available for 7/8" diameter tubes prior to the 1R16 outage. The structural limit is 9.40 volts for a SLB differential pressure of 2405 psi (Reference 8-5). The allowance for growth is 30%/EFPY, which bounds the Beaver Valley Unit-1 historical growth data and is the minimum growth allowance required by Generic Letter 95-05 (Reference 8-1). For the expected Cycle 17 duration of 500 EFPD, the growth allowance becomes 41%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limit is then 9.40/1.61=5.84 volts.

5.0 SLB Analysis Methods

A Monte Carlo analysis technique is used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-16 and projected EOC-17 voltage distributions. The Monte Carlo analysis accounts for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 8-3, and the same methodology was applied to leak and burst analyses performed after the last several outages.

In general, the methodology involves application of correlations for burst pressure, probability of leakage and leak rate to a measured or calculated EOC distribution to estimate the likelihood of tube burst and primary-to-secondary leakage during a postulated SLB event. Uncertainties associated with burst pressure, leak rate probability and leak rate correlations' parameters are explicitly included by sampling distributions for the parameter uncertainties through the Monte Carlo sampling process. NDE uncertainties are also included. The voltage distributions used in the leak and burst projections for the next operating cycle are obtained by applying growth data to the BOC distribution. The BOC voltage distributions include an adjustment for detection uncertainty and occurrence of new indications, in addition to the adjustments for NDE uncertainties. Comparisons of projected EOC voltage distributions with actual distributions after a cycle of operation for a number of plants have shown that the Monte Carlo analysis technique yields conservative estimates for EOC voltage distribution as well as leak and burst results based on those distributions.

The current leak rate calculation methodology (Reference 8-4) considers whether or not a leak rate correlation can be applied. During the Monte Carlo simulations a test is made during each SG simulation to determine whether or not a correlation exists between leak rate and bobbin voltage. A regression correlation is applied for (1-p) fraction of the SG simulations, where "p" is the p-value for the leak rate correlation slope parameter. In the remaining simulations leak is assumed to be independent of bobbin voltage, and the leak rate is based on the mean and standard deviation of the leak data.

Equation 3.5 in Reference 8-3 was used to determine the true BOC voltage. The method of treating fractional indications is discussed in Section 3.6 of Reference 8-3. Fractional indications in the EOC voltage bins are retained, and the tail of the distribution is integrated to define discrete values corresponding to the last 1/3rd and 2/3rd of an indication.

6.0 Bobbin Voltage Distributions

This section describes the salient input data used to calculate EOC bobbin voltage distributions and presents results of calculations to project EOC-17 voltage distributions. Also, EOC-16 voltage projections performed during the last outage based on the EOC-15 inspection bobbin voltage data are compared with the actual bobbin distributions from the current inspection.

6.1 Calculation of Voltage Distributions

The analysis for EOC voltage distribution starts with a cycle initial voltage distribution which is projected to the end of cycle conditions based on the growth rate and the anticipated cycle operating period. The number of indications assumed in the analysis to project EOC voltage distributions, SLB leak rates and tube burst probabilities is obtained by adjusting the number of reported indications to account for detection uncertainty and birth of new indications over the projection period. This is accomplished by using a POD factor, which is defined as the ratio of the actual number of indications detected to total number of indications present. A conservative value is assigned to POD based on historic data, and the value used herein is discussed in Section 6.2. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as follows.

$$N_{Tot\ RTS} = N_i / POD - N_{repaired} + N_{deplugged}$$

where,

$N_{Tot\ RTS}$	=	Number of bobbin indications being returned to service for the next cycle,
N_i	=	Number of bobbin indications (in tubes in service) identified after the previous cycle,
POD	=	Probability of detection,
$N_{repaired}$	=	Number of N_i which are repaired (plugged) after the last cycle,
$N_{deplugged}$	=	Number of indications in tubes deplugged after the last cycle and returned to service in accordance with voltage-based repair criteria.

There are no deplugged tubes returned to service at BOC-17; therefore, Ndeplugged = 0. As noted in Section 3-6, an NRC SER for Beaver Valley-1 (Reference 8-8) allows for consideration of only a fraction of the RPC NDD indications from the current inspection in establishing the BOC voltage distribution for the next cycle. However, all EOC-16 RPC NDD indications were conservatively included in establishing the BOC-17 indication distributions shown in Table 6-1. During the Monte Carlo simulations, voltages for bins with 3 or more indications are selected by randomly sampling the voltage bins. For bins with fewer than 3 indications, each indication is considered to be in a separate bin, and

the actual indication voltage is utilized in the calculations.

The methodology used in the projection of EOC-17 bobbin voltage frequency distributions is described in Reference 8-3, and it is same as that used in performing EOC-16 predictions during the last (EOC-15) outage (Reference 8-2). The salient input data used for projecting EOC-17 bobbin voltage frequency are further discussed below.

6.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 8-1) requires the application of a constant POD value of 0.6 to define the BOC distribution for EOC voltage projections, unless an alternate POD is approved by the NRC. A POD value of 1.0 represents the ideal situation where all indications are detected. A voltage-dependent POD provides a more accurate prediction of voltage distributions consistent with the voltage based repair criteria experience. In this report only the NRC mandated constant POD of 0.6 is used.

6.3 Limiting Growth Rate Distribution

As discussed in Section 3.2, the NRC guidelines in Generic Letter 95-05 stipulate that the more conservative growth rate distributions from the past two inspections should be utilized for projecting EOC distributions for the next cycle. Since the SG A Cycle 15 growth distribution in Figure 3-5 lies to the right of the Cycle 16 distribution for all SGs and has a slightly larger peak growth, it is considered more limiting. Therefore, Cycle 17 operational assessment analysis was carried out using the SG A Cycle 15 distribution. Since the growth distributions for all 3 SGs show slow growth and are close each other for both Cycles 15 and 16, the bounding growth rate for SG A Cycle 15 was conservatively used for all 3 SGs. The Cycle 15 SG A growth distribution was found to be more limiting than the Cycle 16 distribution for all SGs.

Growth distributions used in the Monte Carlo calculations are specified in the form of a histogram, so no interpolation is performed between growth bins. This assures that the largest growth value in the distribution is utilized in the Monte Carlo simulations.

6.4 Cycle Operating Period

The operating periods used in the growth rate/EFPY calculations and voltage projections are as follows.

Cycle 16	-	527.7 EFPD	or	1.45 EFPY	(actual)
Cycle 17	-	500.0 EFPD	or	1.39 EFPY	(projected)

6.5 Projected EOC-17 Voltage Distribution

Calculations for the EOC-17 bobbin voltage projections were performed for all three SGs based on the EOC-16 distributions shown in Table 6-1. The BOC distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-17 is also shown in Table 6-1. Calculations were performed using a constant POD of 0.6. SG A has the largest number of indications at BOC-17.

Cycle 15, SG A growth distribution was found to be more limiting than the Cycle 16 distribution for all SGs. The projected EOC-17 voltage distributions for all three SGs based on the Cycle 15, SG A growth distribution are summarized on Table 6-2. These results are also shown graphically on Figures 6-1 to 6-3.

6.6 Comparison of Actual and Projected EOC-16 Voltage Distributions

Table 6-3 and Figures 6-4, 6-5, and 6-6 provide a comparison of the EOC-16 actual measured bobbin voltage distributions with the corresponding projections performed using the last (EOC-15) inspection bobbin voltage data and presented in Reference 8-2. The EOC-16 projections based on a constant POD of 0.6 are shown. As predicted in Reference 8-2, SG-A has the largest number of indications. A summary of the predicted number of indications and the maximum voltages is given in Table 6-4.

A comparison of the actual and projected voltage distributions computed using the POD = 0.6 show that the indication population above 0.6 volt is substantially overestimated in the projections. Although a POD value of 0.6 is non- conservative for voltages below about 0.5 volt as seen in Figures 6-4, 6-5, and 6-6, the reason for underestimating indications below 0.6 volts is due to the assumption that all new indications appear at the beginning of cycle. Full cycle growth is applied to all new indications in the Monte Carlo simulations, whereas in reality new indications are initiated throughout the cycle and experience only a fraction of the full cycle growth. Therefore, the Monte Carlo projection is conservative.

Table 6-1 Beaver Valley Unit 1
EOC-16 Bobbin and Assumed BOC-17 Bobbin Distributions for SLB Leak Rate and Burst Analysis

	Steam Generator A			Steam Generator B			Steam Generator C		
Voltage	EOC-16		BOC- 17	EOC-16		BOC-17	EOC-16		BOC-17
Bin	Field Bobbin Indications	Indications Repaired	POD = 0.6	Field Bobbin Indications	Indications Repaired	All Indications	Field Bobbin Indications	Indications Repaired	All Indications
0.1	0	0	0.00	0	0	0.00	0	0	0.00
0.2	13	1	20.67	12	0	20.00	12	0	20.00
0.3	60	2	98.00	65	1	107.33	57	0	95.00
0.4	144	8	232.00	116	2	191.33	84	3	137.00
0.5	170	11	272.33	166	2	274.67	102	3	167.00
0.6	252	12	408.00	188	4	309.33	137	6	222.33
0.7	222	13	357.00	174	1	289.00	127	7	204.67
0.8	221	18	350.33	166	6	270.67	110	10	173.33
0.9	245	40	368.33	123	3	202.00	116	12	181.33
1	146	18	225.33	86	2	141.33	76	7	119.67
1.1	107	16	162.33	72	2	118.00	42	1	69.00
1.2	80	4	129.33	40	1	65.67	35	1	57.33
1.3	68	4	109.33	31	3	48.67	37	4	57.67
1.4	34	3	53.67	24	4	36.00	32	2	51.33
1.5	25	3	38.67	20	0	33.33	18	2	28.00
1.6	36	4	56.00	13	1	20.67	22	1	35.67
1.7	23	1	37.33	6		10.00	13	1	20.67
1.8	12	0	20.00	4		6.67	8	0	13.33
1.9	11	1	17.33	6		10.00	8	0	13.33
2	9	1	14.00	2		3.33	7	1	10.67
2.1	5	4	4.33				5	5	3.33
2.2	1	1	0.67				2	2	1.33
2.3	2	2	1.33				4	4	2.67
2.4	1	1	0.67						
2.5									
Total	1887	168	2977.00	1314	32	2158.00	1054	72	1684.67
> 1V	414	45	645.00	218	11	352.33	233	24	364.33
> 2V	9	8	7.00	0	0	0.00	11	11	7.33

Table 6-2 Beaver Valley Unit 1
Projected EC-17 Bobbin Distributions

Voltage Bin	SG A	SG B	SG C
0.1	0.31	0.3	0.3
0.2	8.34	8.44	8.08
0.3	39.78	39.96	34.64
0.4	101.56	95.72	73.81
0.5	180.98	163.52	115.77
0.6	256.52	223.98	153.6
0.7	313.53	259.34	178.63
0.8	337.73	264.14	185.19
0.9	332.55	244.25	175.98
1	302.79	208.58	155.57
1.1	255.17	167.67	128.43
1.2	203.61	129.11	101.44
1.3	157.69	96.64	79.8
1.4	120.29	71.42	63.89
1.5	91.4	52.66	51.82
1.6	69.92	38.81	42.05
1.7	53.99	28.38	33.82
1.8	41.66	20.5	26.77
1.9	31.79	14.58	20.77
2	23.72	10.16	15.81
2.1	17.2	6.91	11.76
2.2	12.09	4.55	8.5
2.3	8.22	2.91	5.98
2.4	5.45	1.8	4.08
2.5	3.5	1.07	2.71
2.6	2.2	0.63	1.75
2.7	1.36	0.36	1.11
2.8	0.82	0.2	0.68
2.9	0.49	0.11	0.41
3	0.28	0.06	0.24
3.1	0.16	0.03	0.14
3.2	0.09	0.02	0.08
3.3	0.05	0.01	0.05
3.4	0.03	0	0
3.5	0.02	0	0
3.6	0.02	0.01	0
3.7	0.05	0.05	0
3.8	0.12	0.1	0
3.9	0.16	0.05	0
4	0.2	0	0
4.1	0.15	0	0.7
4.2	0	0.7	0
4.3	0	0	0
4.4	0.7	0	0
4.5	0	0.3	0.3
4.6	0		
4.7	0.3		
Total	2977.0	2158.0	1684.7
> 1V	1102.9	649.8	603.1
> 2V	53.7	19.9	38.5

Table 6-3 Beaver Valley Unit 1
Comparison of Predicted and Actual EOC-16 Bobbin Voltage Distributions

	Steam Generator A		Steam Generator B		Steam Generator C	
Voltage Bin	POD 0.6	EOC-16 Actual	POD 0.6	EOC-16 Actual	POD 0.6	EOC-16 Actual
0.1	0.4	0	0.4	0	1.3	0
0.2	9.9	13	10.5	12	9.0	12
0.3	40.7	60	39.3	65	33.5	57
0.4	93.8	144	86.6	116	66.3	84
0.5	165.4	170	143.0	166	102.9	102
0.6	238.4	252	190.4	188	134.5	137
0.7	294.2	222	218.8	174	154.7	127
0.8	319.1	221	228.3	166	162.2	110
0.9	312.4	245	220.3	123	155.0	116
1.0	280.9	146	197.0	86	136.6	76
1.1	236.8	107	164.4	72	113.6	42
1.2	191.8	80	130.4	40	91.8	35
1.3	151.5	68	100.2	31	74.3	37
1.4	118.0	34	75.8	24	61.1	32
1.5	91.4	25	57.2	20	50.7	18
1.6	70.8	36	43.4	13	42.3	22
1.7	54.9	23	33.0	6	35.0	13
1.8	42.5	12	25.0	4	28.6	8
1.9	32.7	11	18.9	6	22.8	8
2.0	24.8	9	14.2	2	17.5	7
2.1	18.5	5	10.4		13.0	5
2.2	13.5	1	7.5		9.3	2
2.3	9.6	2	5.3		6.5	4
2.4	6.7	1	3.6		4.4	
2.5	4.5		2.5		2.9	
2.6	3.0		1.6		1.9	
2.7	1.9		1.0		1.3	
2.8	1.3		0.7		0.8	
2.9	0.8		0.4		0.6	
3.0	0.5		0.3		0.4	
3.1	0.3		0.1		0.2	
3.2	0.2		0.0		0.0	
3.3	0.1		0.0		0.0	
3.4	0.1		0.0		0.7	
3.5	0.1		0.7		0.0	
3.6	0.0		0.0		0.0	
3.7	0.0		0.0		0.0	
3.8	0.0		0.0		0.0	
3.9	0.0		0.0		0.0	
4.0	0.0		0.0		0.0	
4.1	0.0		0.0		0.0	
4.2	0.0		0.0		0.0	
4.3	0.1		0.0		0.0	
4.4	0.1		0.0		0.0	
4.5	0.1		0.0		0.0	
4.6	0.1		0.0		0.0	
4.7	0.0		0.0		0.3	
4.8	0.0		0.3			
4.9	0.7					
5.0	0.0					
5.1	0.0					
5.2	0.0					
5.3	0.3					
TOTAL	2833.0	1887.0	2031.4	1314.0	1535.7	1054.0
> 1 V	1077.7	414.0	696.9	218.0	579.8	233.0
> 2 V	62.7	9.0	34.4	0.0	42.2	11.0

Table 6-4 Beaver Valley Unit 1
Summary of Number of Indications and Maximum Voltages Predicted and Actual at EOC-16

	Number of Indications		Maximum Voltage	
	Predicted	Actual	Predicted	Actual
	POD = 0.6		POD = 0.6	
SG A	2833	1887	5.3	2.32
SG B	2031	1314	4.8	1.99
SG C	1536	1054	4.7	2.29

Figure 6-1
Beaver Valley Unit 1 SG A
Predicted Bobbin Voltage Distribution for Cycle 17

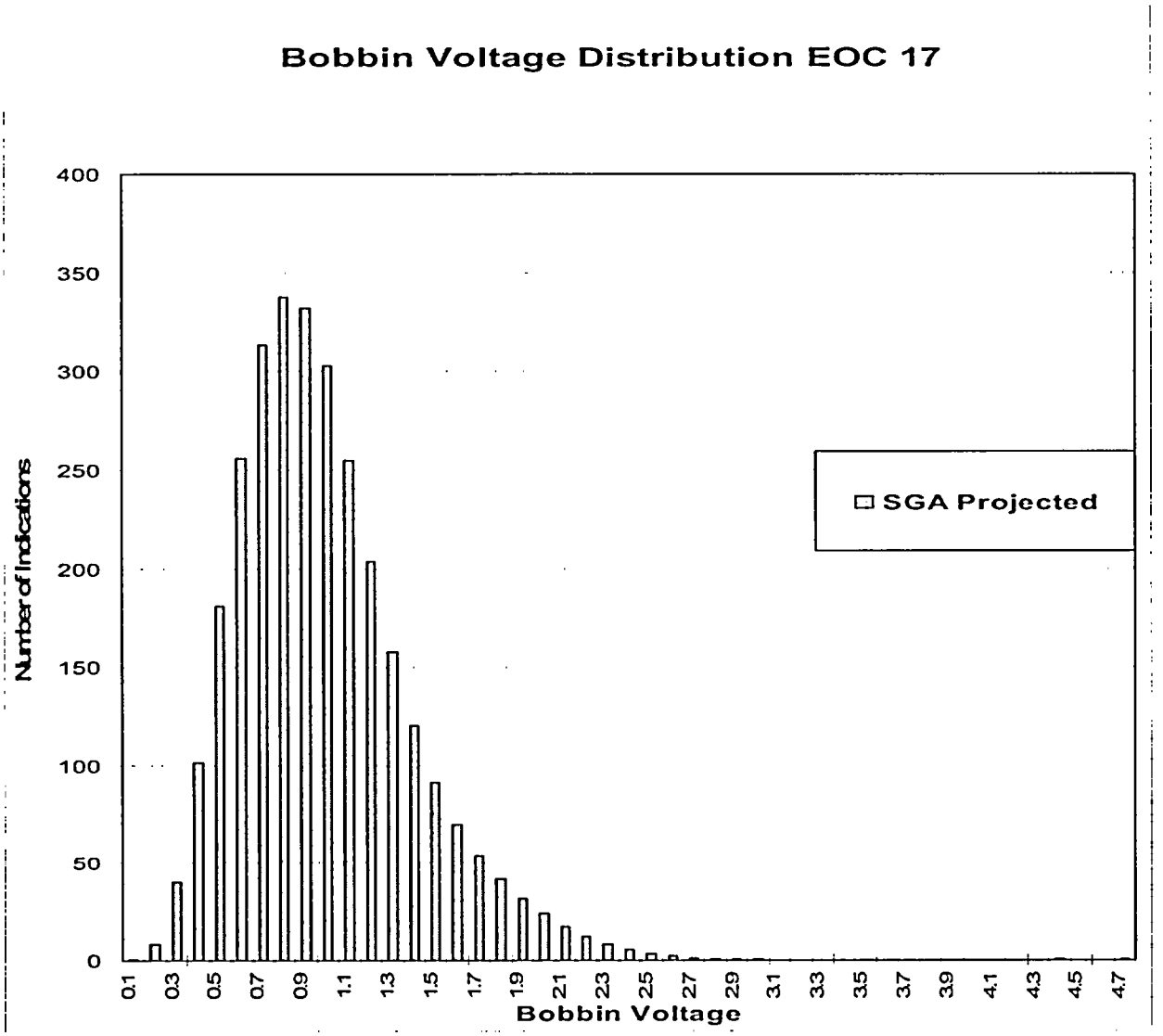


Figure 6-2
Beaver Valley Unit 1 SG B
Predicted Bobbin Voltage Distribution for Cycle 17

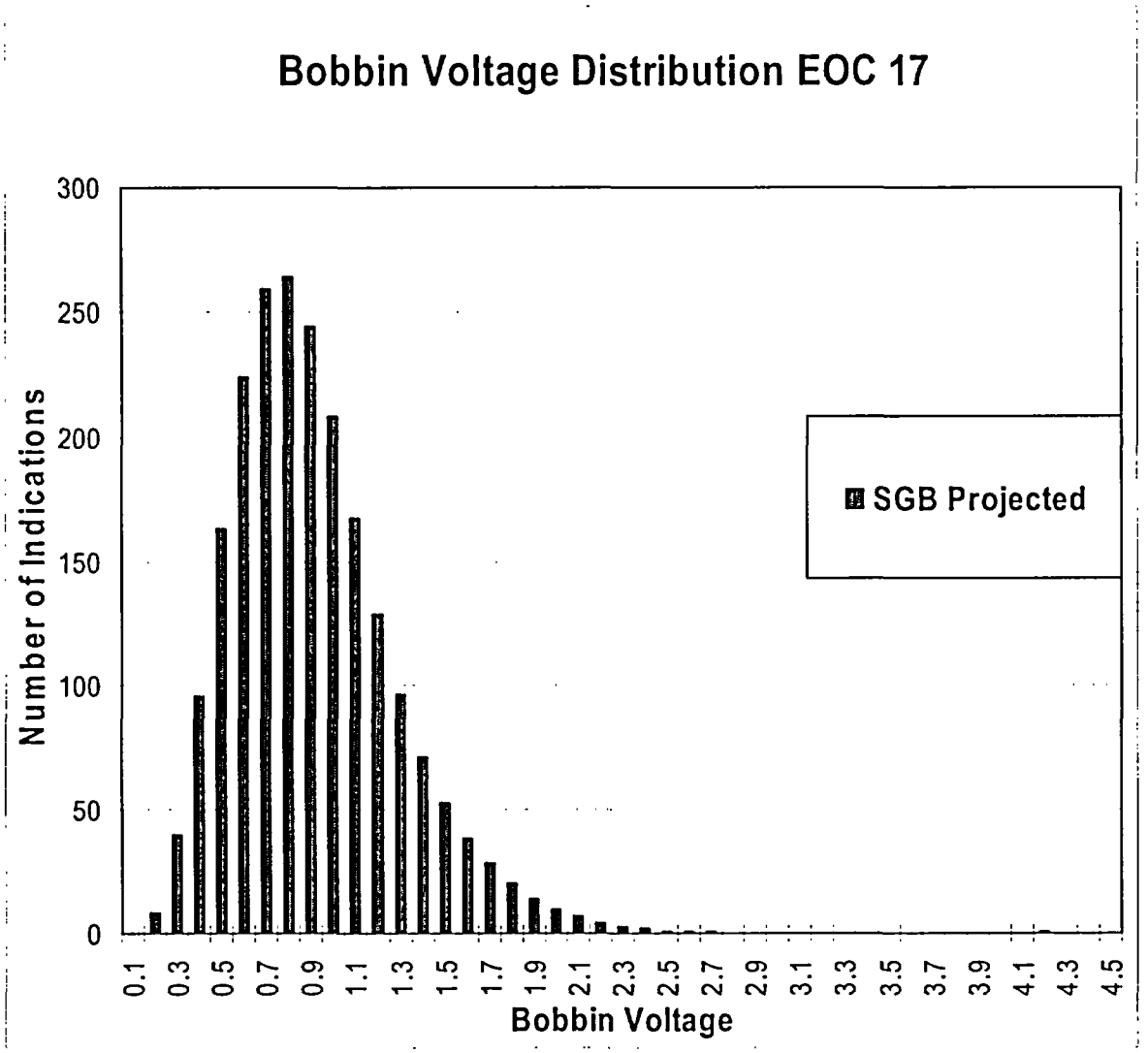


Figure 6-3
Beaver Valley Unit 1 SG C
Predicted Bobbin Voltage Distribution for Cycle 17

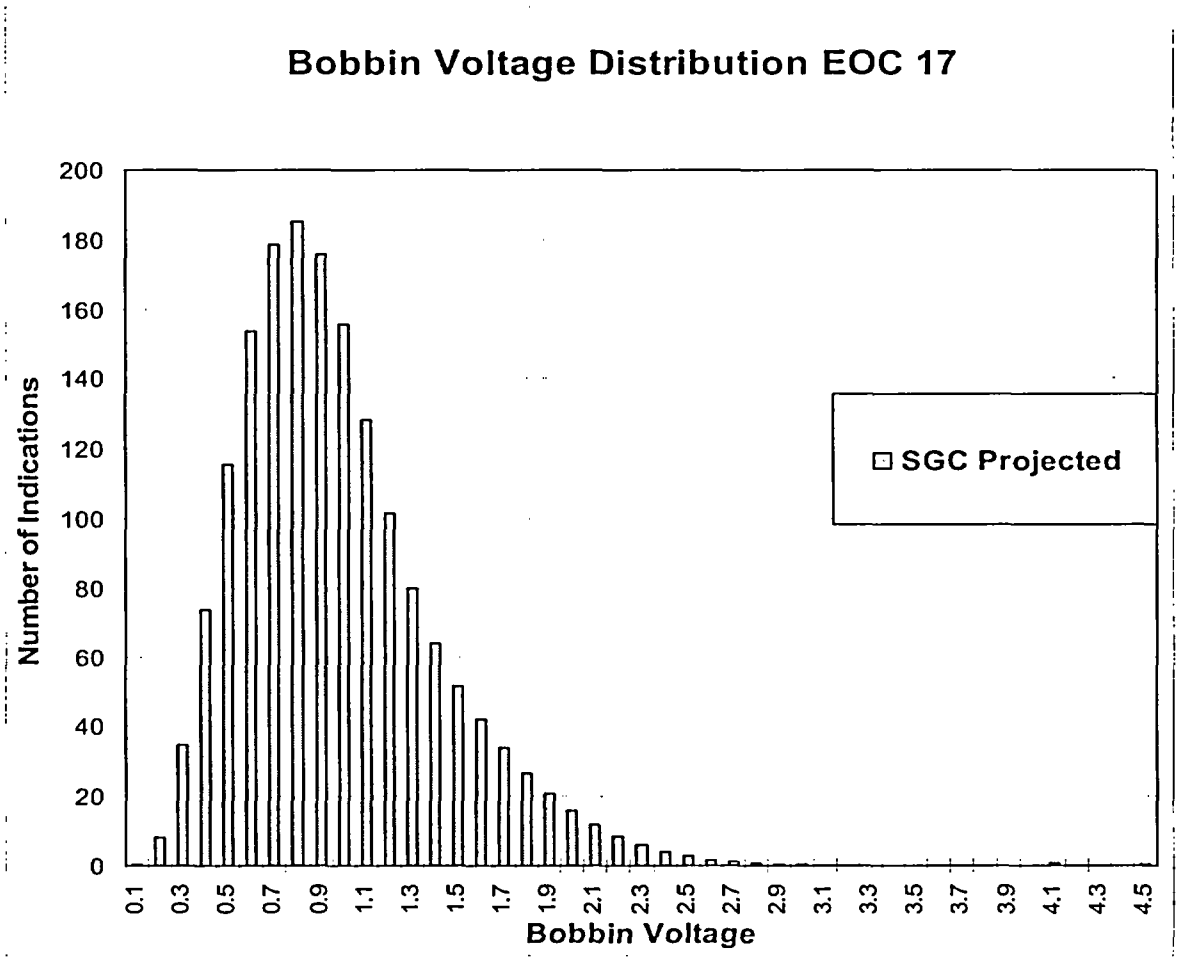


Figure 6-4
Beaver Valley Unit 1 SG A
Comparison of Predicted Bobbin Voltage (POD = 0.6) and Actual Measured Values at EOC-16

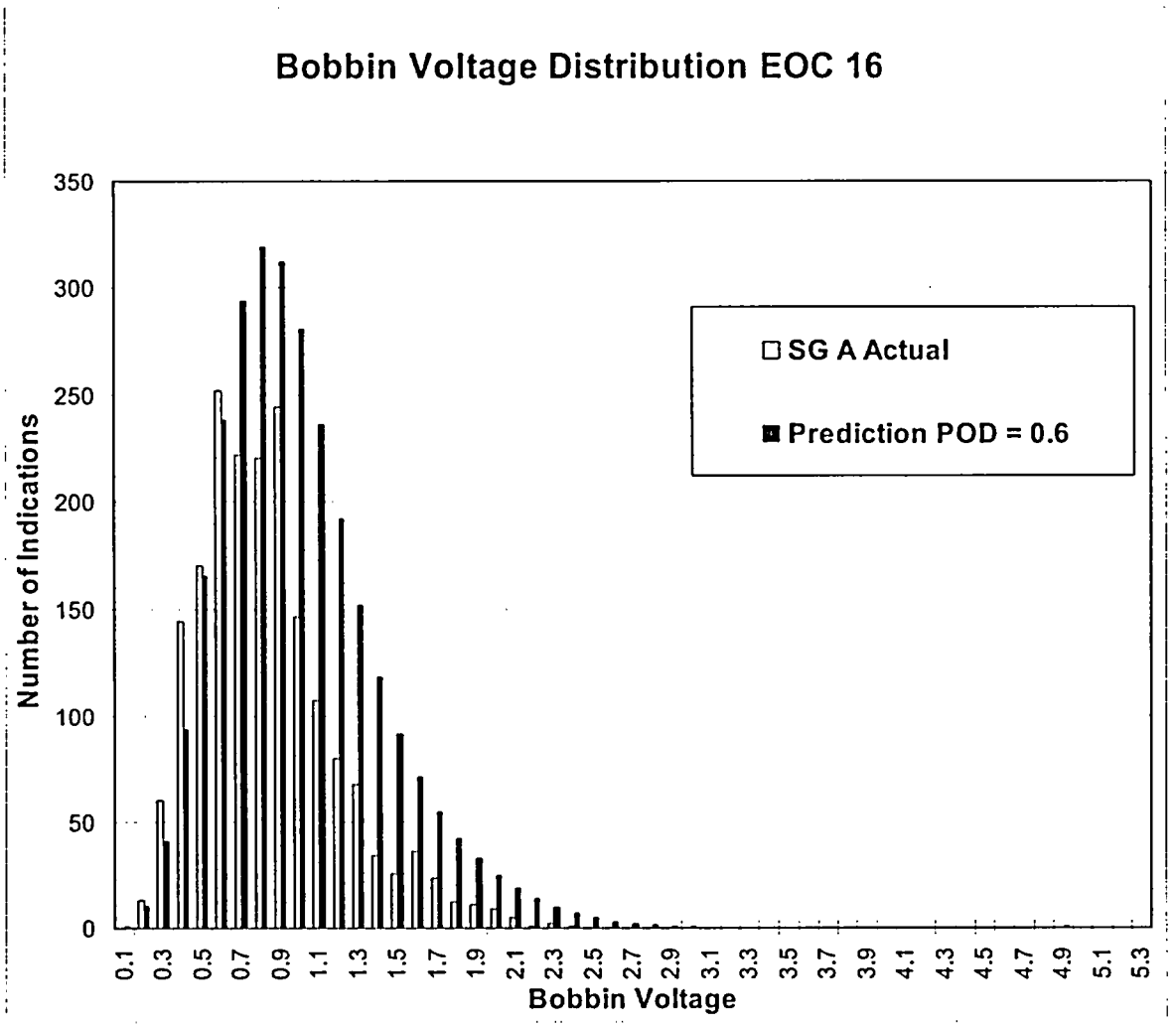


Figure 6-5
Beaver Valley Unit 1 SG B
Comparison of Predicted Bobbin Voltage (POD = 0.6) and Actual Measured Values at EOC-16

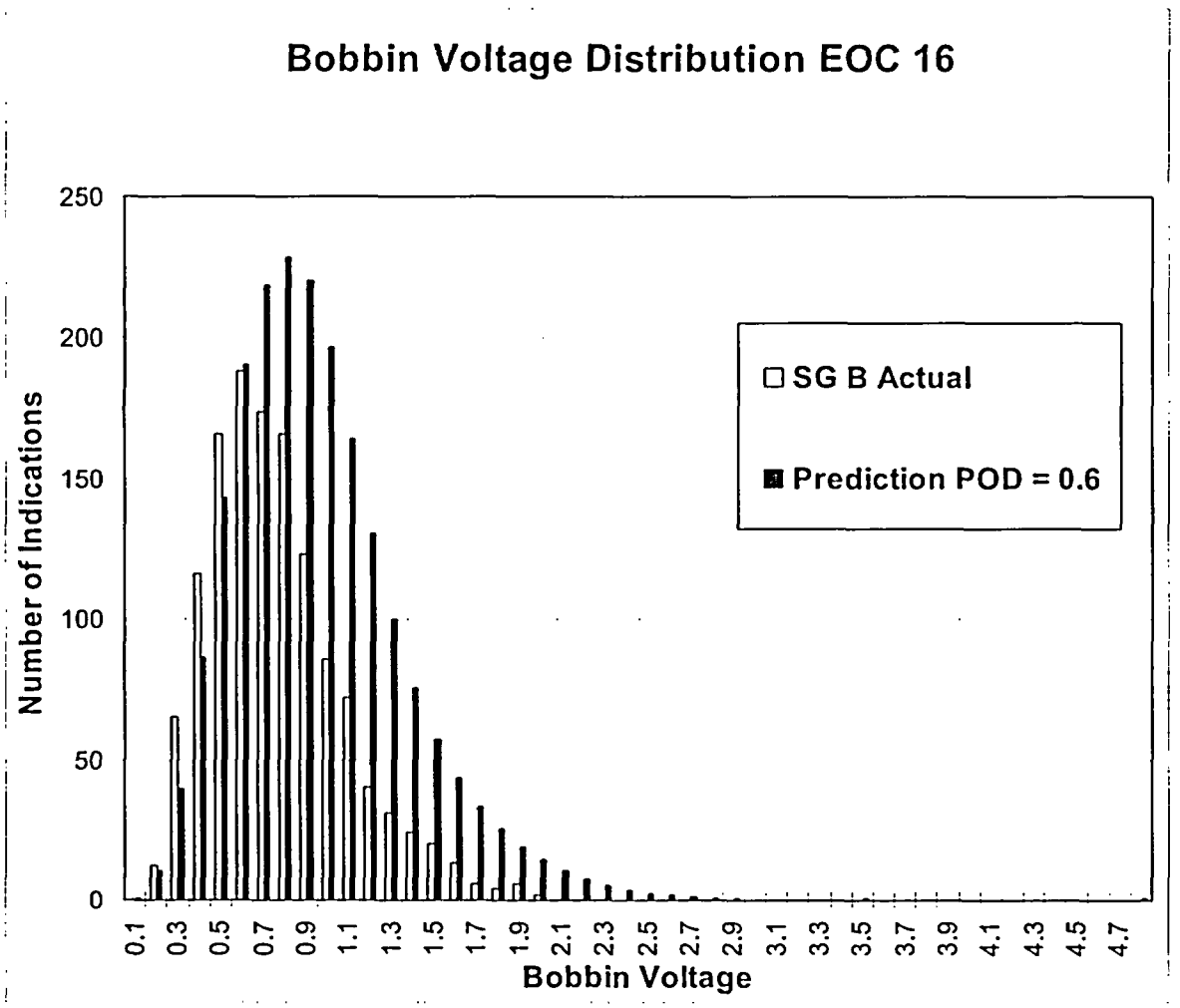
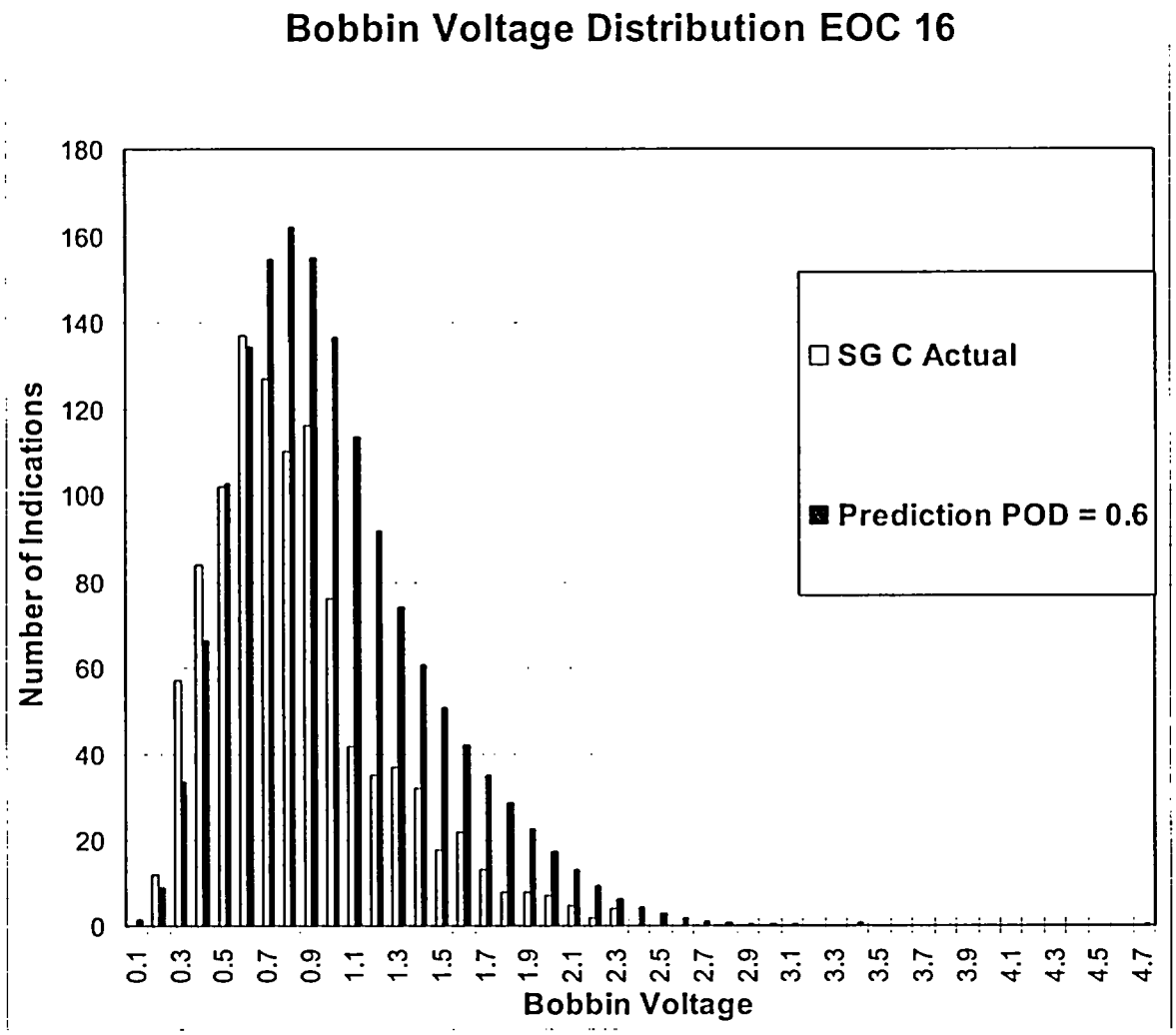


Figure 6-6
Beaver Valley Unit 1 SG C
Comparison of Predicted Bobbin Voltage (POD = 0.6) and Actual Measured Values at EOC-16



7.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents the results of the analyses carried out to predict leak rates and tube burst probabilities at the postulated SLB conditions using the actual voltage distributions from the EOC-16 inspection (condition monitoring assessment) as well as for the projected EOC-17 voltage distributions (operational assessment). The methodology used in these analyses is described in Section 6.0. SG-A with the largest total number of indications as well as indications over 1 volt is expected to yield the limiting SLB leak rate and burst probability for Cycle 17.

7.1 EOC-16 Condition Monitoring Leak Rate and Tube Burst Probability

Analyses to calculate the EOC-16 SLB leak rates and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Table 6-1. The results of Monte Carlo calculations are summarized on Table 7-1. A comparison of the EOC-16 condition monitoring results in Table 7-1 with the corresponding Cycle 16 operational assessment, Reference 8-2, also shown in Table 7-1, indicates the following.

a) Total number of indications found in the EOC-16 inspection for all three SGs are well below their projections based on POD=0.6.

b) The leak rates predicted by the Cycle 16 operational assessment are conservative relative to EOC-16 condition monitoring values for all SGs. The corresponding tube burst probability values are conservatively predicted by the analysis with POD = 0.6.

c) As predicted, SG-A was confirmed as the limiting steam generator at EOC-16 based on the SLB leak rate and tube burst probability analysis using the actual EC bobbin measurements for EOC-15.

d) The limiting values for SLB leak rate (0.775 gpm at room temperature) and tube burst probability (2.9×10^{-4}) obtained using the actual measured voltages are well below the allowable SLB leakage limit effective at EOC-16 (14.5 gpm) and the NRC reporting guideline of 10^{-2} for the tube burst probability.

In summary, the EOC-16 condition monitoring results are lower than the Cycle 16 operational assessment results obtained using the NRC mandated probability of detection of 0.6 and are well within the allowable limits.

7.2 Cycle 17 Operational Assessment Leak Rate and Tube Burst Probability

The SLB leak rate and tube burst probability projection for the Cycle 17 operational assessment was carried out using the latest update to the ARC database documented in Reference 8-5. Since credit can be taken for operability of the pressurizer PORV during a SLB event (Reference 8-7), the EOC-17 leak and burst analyses were performed using a primary-to-secondary pressure differential of 2405 psi.

SG-A is again predicted to be the limiting SG. Reference calculations for the EOC-17 SLB leak rate using the ARC database documented in Reference 8-5 show that for a cycle duration of 500 EFPD the limiting EOC-17 leak rate, calculated for SG-A using the NRC mandated constant POD of 0.6, is equal to 1.91 gpm (room temperature), which is considerably less than the current limit of 14.5 gpm. The limiting burst probability for SG-A, also calculated with POD=0.6, is 8.5×10^{-4}, which is an order of magnitude below the NRC reporting guideline of 10^{-2}. Table 7-2 provides the SLB leak rates and tube burst probabilities calculated for all 3 SGs using the constant POD of 0.6.

Table 7-1 Beaver Valley Unit 1
Leak and Burst Results for EOC-16

SG	SLB Leak Rate, gpm (Room Temp.) 95th percentile with 95% confidence			Conditional Burst Probability 95% confidence		
	Cycle 16 Operational Assessment POD = 0.6	EOC-16 Condition Monitoring (Add. 5)	EOC-16 Condition Monitoring (Add. 6)	Cycle 16 Operational Assessment POD = 0.6	EOC-16 Condition Monitoring (Add. 5)	EOC-16 Condition Monitoring (Add. 6)
SG-A	3.58	1.50	0.790	1.0×10^{-3}	2.8×10^{-4}	2.5×10^{-4}
SG-B	2.24	0.737	0.385	5.4×10^{-4}	1.4×10^{-4}	1.7×10^{-4}
SG-C	2.04	0.900	0.494	5.4×10^{-4}	2.5×10^{-4}	2.3×10^{-4}

Table 7-2 Beaver Valley Unit 1
Predicted Leak and Burst Results for Cycle 17
(POD = 0.6)

	Number of Indications	Maximum Volts	Probability of Burst, 95% confidence	SLB Leak Rate , gpm at room temp at 95/95 confidence
SG-A	2977	4.7	8.5×10^{-4}	1.91
SG-B	2158	4.5	4.8×10^{-4}	1.08
SG-C	1684.7	4.5	5.9×10^{-4}	1.18

8.0 References

8-1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

8-2 SG-SGDA-03-25, "Beaver Valley Unit-1 Cycle 16 Voltage-Based Repair Criteria 90-Day Report," Westinghouse Electric Company, July 2003.

8-3 WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections", Westinghouse Nuclear Services Division, December 1996.

8-4 NRC letter from William H. Bateman to Alex Marion (NEI), "Refining the Leak Rate sampling Methodology for Generic Letter 95-05 Voltage-Based Alternate Repair Criteria Application," March 27, 2002.

8-5 EPRI Report TR-1011456, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits, NP 7480-L, Addendum 6, 2004 Database Update, " October 2004.

8-6 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Research Institute, February 9, 1996.

8-7 Beaver Valley Unit-1, Updated Final Safety Analysis Report, March 2002.

8-8 U.S. N.R.C. Report, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 198 to Facility Operating License DPR-66 Duquesne Light Company, Ohio Edison Company and Pennsylvania Power Company, Beaver Valley Power Station, Unit No. 1 Docket No. 50-334", April 1, 1996.

8-9 EPRI Report 1007660, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits, NP 7480-L, Addendum 5, 2002 Database, " November 2002.

8-10 E-mail from G. Alberti of First Energy Corp to W. Cullen of Westinghouse, "Re: EFPD data", October 30, 2004 12:05PM.

Appendix A
BVPS Unit 1 1R16 Tubesheet Region PWSCC Leak Rate Estimation

During the 1R16 outage only 5 tubes were reported with PWSCC within the expanded portion of tube in tubesheet, including the expansion transition. This number was far below the predicted value of 25 which was included as part of LAR-1A-328 (W*). The reduction may be associated with zinc addition which was initiated just before the 1R15 outage and continued throughout the Cycle 16 operating period.

In general, the indications observed during 1R16 were bounded by the indications reported in previous outages. The following table presents a summary of the 1R16 tubesheet region PWSCC indications, including bottom of WEXTEX transition (BWT) location. No circumferential PWSCC indications were reported at 1R16.

SG	Tube	BWT (ref. to TSH)	Flaw Reference Location	Ind. Type	+Point Volts	Length from Profiling	Length from Resolution (initial reporting)	Max Depth by Phase	Max Depth by +Point Volts
A	R5 C58	-0.51"	TSH -1.18"	SAI	0.78	0.43"	0.41"	46%	49%
A	R35 C27	-0.40"	TSH -0.18"	SAI	0.89	0.12"	0.21"	48%	51%
B	R15 C78	-0.29"	TSH -1.27"	SAI	1.06	0.42"	0.38"	47%	56%
B	R35 C52	-0.42"	TSH -1.09"	SAI	0.62	N/A	0.20"	25%	44%
B	R43 C37	-0.38"	TSH -1.69"	SAI	0.48	N/A	0.13"	35%	39%

Notes: SAI: Single Axial Indication, TSH: Top of tubesheet hot leg side

Leakage Estimation

TTS to 8 Inches Below

None of the reported indications represent a 100%TW condition based on the observed NDE parameters, therefore, no primary to secondary leakage would have occurred if a steam line break event was experienced just prior to shutdown. When maximum depth sizing uncertainty consistent with the EPRI ETSS and the EPRI Tube Integrity Guideline is considered, the deepest NDE adjusted maximum depth is 66%TW, which is well below the breakthrough depth associated with leakage from freespan indications of 95%TW. Flaw Plus Point coil amplitude can also be used to estimate maximum depth. Based on the observed 1R16 axial PWSCC Plus Point amplitude of 1.06 volts, the NDE adjusted maximum depth is 74%TW, which also is well below the breakthrough depth associated with leakage from freespan indications of 95%TW.

8 to 12 Inches Below TTS:

Inclusion of the 1R16 data to the prediction of indications located greater than 8 inches below TTS does not affect the predicted number of indications presented in LAR 1A-328. The regression estimates 12 indications within this range. Based on the information provided in LAR 1A-328, at the upper 90% prediction the estimated leakage from 12 indications is 0.054 gpm for postulated SLB conditions. However, in LAR 1A-328, FENOC committed to assume 32 indications within this range if the observed 1R16 indication count was less than 32. For 32 indications, the upper 90% leakage prediction is 0.144 gpm. Note that the indications assumed present within this elevation range are assumed to represent a circumferentially separated condition.

Greater than 12 Inches Below TTS:

LAR 1A-328 conservatively assumed that all active tubes contain a complete circumferential separation below the tubesheet neutral axis. SG-C contains the largest number of active tubes at 2873. Using the upper 90% prediction of leak rate at postulated SLB conditions, the leakage contribution for indications located greater than 12 inches below the top of tubesheet is 9 x 10-5 gpm. Therefore, for 2873 active tubes, postulated leakage from this section of tubing is 0.259 gpm. It should be noted that this leakage allowance is considered to be extremely conservative based on the assumption that all tubes contain a complete circumferential separation just below the tubesheet neutral axis. For the 1R15 outage, an estimation of the actual average Plus Point inspection below the top of tubesheet was performed for SG-C. Using the actual tube counts per calibration group, approximately 10% of the active tubes are found in calibration groups where the average inspection distance is greater than 12 inches below top of tubesheet. The lowest PWSCC depth reported for the 1R15 outage was 9.79 inches below the top of tubesheet, and this indication was the only indication located at greater than 8 inches below the top of tubesheet. If 5% of the tubes in SG-C at 1R15 were assumed to have been inspected to >12 inches below the top of tubesheet, with no indications observed at greater than 12 inches below the top of tubesheet, the following table presents the probability of detecting at least one indication at 95% confidence for varying numbers of assumed defects within the total population. The sample size is assumed to represent the number of tubes inspected to greater than 12 inches below the top of tubesheet.

BVPS 1R15 SGC Probability of Detecting One Defect at 95% Confidence			
Population	Assumed Defects	Sample Size	Probability of Detecting One Defect
2900	29	58	45%
2900	145	58	95%
2900	290	58	99.8%
2900	580	58	100%
2900	29	145	78%
2900	145	145	99.9%
2900	290	145	100%
2900	580	145	100%
2900	29	290	95%
2900	145	290	100%
2900	290	290	100%
2900	580	290	100%

The above table shows that the assumption that all tubes contain a complete circumferential separation at the tubesheet neutral axis is extremely conservative as no defects were reported, and the probabilities of detecting one indication are high for relatively small sample sizes.

A similar calculation can also be performed to estimate the number of defects that could be present based on a sample size and associated confidence level. For the case of 145 samples with a population of 2900 (5% of the tubes inspected to at least 12 inches below the top of tubesheet), at 95% confidence, for no observations, 57 defects could be present. In this case, the postulated SLB conditions leakrate is 0.005 gpm. For the case of 290 samples with a population of 2900 (10% of the tubes inspected to at least 12 inches below the top of tubesheet), at 95% confidence, for no observations, 28 defects could be present.

Conclusion

Section 4.3.7 of LAR-1A-328 states that the total EOC-17 leakage can be estimated by summing the individual leakage sources, as described by the following;

$$SLBLeakage_{Cycle17} = ARC_{GI95-05}$$
$$+ AssumedLeakage_{0-8"<TTS} + AssumedLeakage_{8-12"<TTS} + AssumedLeakgae_{>12"belowTTS}$$

Therefore, projected total SLB conditions leakage at EOC-17 is;

$$SLBLeakage_{Cycle17} = 1.91gpm + 0.000gpm + 0.144gpm + 0.259gpm = 2.313gpm$$

which is well below the limit of 14.5 gpm for a postulated SLB event.

Per LAR 1A-328, the total postulated SG leakage at SLB conditions for all leakage sources was committed to be supplied. This total postulated leakage is the sum of postulated tubesheet region PWSCC leakage per LAR 1A-328, calculated leakage from TSP ODSCC per GL 95-05, and Alloy 800 sleeve installation. The leakage contribution from tubesheet region PWSCC is 0.403 gpm, for TSP ODSCC is 1.91 gpm (per Table 7-2). As no alloy 800 sleeves were installed at 1R16, the total postulated SLB condition leakage at EOC-17 is 2.313 gpm, which is well below the 14.5 gpm limit.

Appendix B
Synopsis of BVPS 1R16 Condition Monitoring Evaluation

Per NEI 97-06, when the results of a steam generator inspection fall into the C-3 category, a summary of the condition monitoring report is to be provided to NRC. Such a condition was reported for the BVPS 1R16 outage, conducted in October 2004. The following is a summary of the BVPS 1R16 condition monitoring report.

Initial Inspection Scope

The Beaver Valley 1R16 inspection plan exceeded both the Technical Specification minimum requirements as well as the recommendations of EPRI 1008138, PWR Steam Generator Examination Guidelines: Revision 6. The 1R16 initial inspection plan included:

1) 100% full length 0.720" bobbin examination (Rows 5 and up), 100% 0.720" bobbin examination of hot and cold leg straight sections in Rows 1 thru Row 4, per GL 95-05
2) 100% 0.700" bobbin examination in U-bend region of Rows 3 and 4
3) 100% +Pt inspection of TSP ODSCC indications ≥ 2.0 volts per GL 95-05
4) 100% +Pt inspection at dented TSP intersections ≥ 5 volts
5) 100% hot leg TTS +Pt inspection in each SG from 6" above to 8" below TTS
6) 100% Row 1 and 2 small radius U-bend mid-range +Pt inspection in each SG
7) 100% +Pt inspection of SG A cold leg expanded TSP intersections
8) 100% +Pt inspection of laser welded sleeve weld joints
9) 100% 0.640" bobbin examination of laser welded sleeves and tube sections between sleeves
10) 100% +Pt inspection of laser welded sleeve lower hardroll joints
11) 100% +Pt inspection of freespan dings >2 volts but <5 volts from hot leg TTS to 03H and dented 01H, 02H, and 03H TSP intersections >2 volts but <5 volts
12) 100% +Pt inspection of hot leg freespan dings > 5 volts
13) 100% +Pt inspection of freespan signals not resolved as MBMs or without historical review
14) 20% +Pt inspection of bobbin cold leg thinning indications
15) +Pt sampling of the 100 largest amplitude DSI indications < 2.0 volts in each SG for confirmation of the degradation mechanism as axial ODSCC
16) 100% +Pt inspection of mix residuals ≥1.5V to determine if axial ODSCC is present

17) 20% +Pt inspection of U-bend regions in Rows 3 thru 7 and Rows 12 thru 18
18) 20% cold leg +Pt inspection from 6" above to 8" below TTS in SGB

The inspection plan was developed to specifically address the areas of active degradation as well as areas expected to be affected based on recent industry experience as well as experience from the BVPS 1R15 outage in April 2003.

Based on the observed degradation during the 1R16 outage, the following expansion programs were implemented;

- 100% +Pt inspection of dents >2V but <5V at 04H thru 07H in SGA

Observed 1R16 Degradation Mechanisms

Indications suggestive of the following degradation mechanisms were detected in the BVPS 1R16 inspection:

- Axial ODSCC at non-dented TSP intersections
- Axial ODSCC at dented TSP intersections
- Axial ODSCC in the hot leg sludge pile freespan region and expansion transition region
- Circumferential ODSCC at the hot leg TTS expansion transitions
- Mixed Mode ODSCC at the hot leg TTS expansion transition in SGA
- OD Thinning at peripheral cold leg TSP intersections
- Wear at AVB sites
- Parent tube degradation in the lower hardroll joint region of laser welded sleeves
- Volumetric degradation at the top of tubesheet not associated with corrosion mechanisms

No indications exceeded the testing criteria established by the EPRI In Situ Testing Guidelines Revision 2 based on depth profiling, however, one indication was conservatively pressure tested. The indication pressure tested was a mixed mode ODSCC signal at the top of tubesheet. No leakage or burst was reported. In general, the voltage magnitudes and lengths of identified degradation at the TTS were consistent with or below previously observed limiting indication levels that were in situ tested at 1R12, 1R14, and 1R15, or pulled for destructive examination.

The following table presents a listing of plugged tubes according to the observed degradation mechanism. In some cases one tube may contain more than one repair mechanism.

BVPS 1R16 Tube Repair Summary				
Mechanism	SGA	SGB	SGC	Tota l
Axial ODSCC at TTS detected by +Pt	26	20	18	64
Nonconfirmed bobbin signal in sludge pile region	0	0	2	2
>2V DSI	8	0	11	19
Confirmed SPR no bobbin signal	43	6	16	65
TSP ODSCC extending beyond TSP	1	0	0	1
TSP ODSCC detected by 640 wide groove bobbin	0	1	N/A	1
Dented TSP with Axial ODSCC	3	0	0	3
Circ ODSCC at TTS	1	2	1	4
Mixed Mode ODSCC at TTS	1	0	0	1
Axial PWSCC in expanded tubesheet	2	3	0	5
AVB wear	0	0	0	0
Cold Leg Thinning	1	1	0	2
Parent Tube Degradation in sleeved tubes	20	3	N/A	23
Volumetric Degradation not associated with loose parts	0	3	2	5
Preventive	2	1	2	5
Total Repairable Signals	108	40	52	200
Total Number Plugged Tubes	104	40	52	196

Condition Monitoring of 1R16 Observed Degradation Mechanisms

Condition monitoring evaluation of 1R16 indications was performed by comparing the predicted burst pressure with allowance for NDE uncertainty and material properties, evaluated at probability and confidence levels consistent with the EPRI Tube Integrity Guidelines against the three times normal operating pressure differential of 4375 psi.

Axial ODSCC at Hot Leg Top of Tubesheet Region

A total of 66 tubes were reported with axial ODSCC indications in the historic sludge pile region or expansion transition. Sixty four of these were reported by the +Pt coil, 2 were reported by bobbin coil but not confirmed by the +Pt coil. All 66 tubes were repaired by plugging.

The 1R16 axial ODSCC +Pt length and amplitude distributions were bounded by or consistent with the 1R14 and 1R15 distributions. The limiting indication with regard to burst pressure was R20 C41 in SGA. The predicted burst pressure using the phase based depth and length was 5134 psi. This signal was located in the expansion transition, and the phase responses are distorted due to the geometry influence of the expansion transition resulting in an overestimate of the flaw depth. Using a correlation of +Pt amplitude to depth, the predicted burst pressure is 6606 psi. Due to the length of this indication, 0.25", a depth profile was not performed. The flaw model assumed that the reported maximum depth existed over the entire length of the flaw, which is conservative.

Figure B-1 presents a cumulative distribution plot of sludge pile axial ODSCC length for the last 3 inspections. The 1R16 distribution is consistent with the 1R15 and 1R14 distributions. Figure B-2 presents a cumulative distribution plot of sludge pile axial ODSCC +Pt amplitude for the last 3 inspections. The 1R16 distribution is consistent with the 1R15 and 1R14 distributions.

The peak +Pt amplitude of 0.26 volt in 300 kHz is well below the in situ proof testing threshold of 0.50 volt and well below the in situ leakage testing threshold of 1.0 volt for expansion transition locations.

Circumferential ODSCC at the Hot Leg Top of Tubesheet Expansion Transition

A total of 5 tubes were reported with circumferential ODSCC indications in the expansion transition. The largest reported circumferential arc length was 72°, which is well below the 100%TW critical flaw angle of 277°, or 77% percent degraded area (PDA). The NDE adjusted PDA of the limiting indication was <43%, which is well below the structural limit of 77%.

One of the 5 tubes with circumferential ODSCC includes a mixed mode indication. While the individual flaw amplitudes did not exceed the 0.5 V in situ pressure testing threshold, this indication was conservatively pressure tested. No leakage was reported at 2941 psi and no burst was reported at 5030 psi.

The maximum +Pt amplitude of 0.22 volt is well below the in situ proof testing threshold of 0.5 volt and well below the in situ leakage testing threshold of 1.31 volts.

Tube Support Plate Axial ODSCC

A total of 20 indications were reported with DSI amplitudes ranging from 2.01 to 2.32 volts. Nineteen of these were confirmed by +Pt as axial ODSCC and

repaired. The 2.08V indication which was not repaired had no growth from the 1R15 inspection. This indication was also +Pt inspected at 1R15 and was also not confirmed. The 1R16 peak voltage of 2.32 volts was substantially below the peak voltages reported for the 1R15 and 1R14 outages of 4.57 and 5.3 volts, respectively. The upper voltage repair limit established for BVPS Unit 1 is 5.97 volts and significantly bounds the maximum 1R16 DSI voltage of 2.32 volts. The Cycle 16 TSP ODSCC growth rates were bounded by the Cycle 15 and Cycle 14 growth distributions. The total number of indications exceeding 2V has remained essentially constant since the application of chemical cleaning at 1R14. Application of chemical cleaning at 1R14 appears to have also had a positive effect on TSP ODSCC growth rates. The observed TSP ODSCC growth rate trend for BVPS Unit 1 shows a decreasing trend whereas the growth rate trending for other units with a significant number of TSP ODSCC indications has shown an increasing trend in the later cycles of operation.

A total of 65 tubes were reported with axial ODSCC at TSP intersections with no corresponding bobbin DSI report. All were repaired by plugging. These signals were reported for intersections with a mix residual exceeding 1.5 volts in the primary mix channel. The bobbin DSI amplitudes for these indications were estimated using a correlation of +Pt and bobbin amplitude developed consistent with the latest version of the TSP ODSCC Database Addendum. The maximum estimated DSI amplitude from this subset of indications was 1.26 volts. The maximum depths of these indications was estimated from the +Pt amplitude response. The estimated average maximum and peak maximum depths are 48%TW and 72%TW.

Three tubes were also repaired due to observation of axial ODSCC in dented TSP intersections for which the dent amplitude was <5V by bobbin. No dent ODSCC was observed in >5V dented TSP intersections. While these intersections were not required to be plugged according to GL 95-05, they were conservatively repaired. The maximum +Pt amplitude for these intersections was 0.27 volt. At this amplitude the estimated maximum depth is 55%TW. Two additional tubes contained axial ODSCC in <5V dented TSP intersections that contained indications at other locations that were considered the primary plugging attribute, such as axial ODSCC in the sludge pile or confirmed axial ODSCC in a >2V DSI.

One tube was reported to contain axial ODSCC that extended beyond the edge of a TSP. NRC was notified of this condition during the outage. The total flaw extension beyond the TSP was reported at <0.10". A residual sludge deposit was noted at this location in the 1R12 RPC examination. The position of the sludge deposit is aligned with the dominant ODSCC signal, however, no flaw extension could be observed in the 1R12 RPC data. Note the inspection coil used at this time was the 115 mil pancake coil. This DSI has been reported

since the 1R10 outage with essentially no growth. The reported DSI amplitude at 1R10 was 1.35 volts, the reported DSI amplitude at 1R16 was 1.33 volts.

Axial PWSCC in the Expanded Tubesheet Region

At 1R16, 5 axial PWSCC indications were reported in the tubesheet region. One was located in the expansion transition and the remaining 4 were located between 1 and 1.7" below the top of tubesheet. As no PWSCC was reported below this length this observation supports the assumption that PWSCC initiation at deep depths below TTS is related to geometry discontinuities within the tube and does not represent a significant initiation potential below the inspected length of tube within the tubesheet. Due to the observed elevation of the 4 deeper indications, burst is precluded due to tubesheet proximity. The single indication observed in the expansion transition was reported with a length of 0.21" by resolution. This indication was also depth profiled with a length from profiling of 0.12". The upper 90% probability axial length uncertainty for axial PWSCC as developed from the ETSS 21510.1 database is 0.10", thus the indication length adjusted for NDE uncertainty is well below the 100%TW critical flaw length of 0.42".

The number of observed axial PWSCC indications within the expanded tubesheet region is modestly reduced compared to previous inspections. This observation could be related to zinc addition, which was initiated just prior to the 1R15 inspection.

OD Thinning at Cold Leg TSP Intersections

This degradation mechanism has been reported at Beaver Valley Unit 1 for many cycles. In SGs A and B, one cold leg thinning indication was reported with a depth $\geq$ 40%TW and were subsequently repaired by plugging. The maximum reported CLT depth of 56% occurred in SGA. This indication was reported in the 1R15 inspection with a depth of 0%, however, the reported bobbin amplitudes for both outages show no change. The bobbin amplitude for this location was only 0.31 volt, and is uncharacteristically low for cold leg thinning. Cold leg thinning depth sizing is often highly uncertain for low voltage signals such as this. RPC +Pt testing showed an axial involvement of 0.33", circumferential involvement of 50°, with maximum amplitude of 0.20 volt. Depth estimates from RPC were performed using several different techniques. Using an amplitude versus depth method that calibrated the response using the flat bottom holes of the ASME standard, a maximum depth of 10% was achieved. Using a phase versus depth technique that calibrated the response using the flat bottom holes of the ASME standard, a maximum depth of 0% was achieved. The information regarding this indication can therefore be used to establish a position that the bobbin based depth of

56%TW is unreliable. The other repairable CLT indication occurred in SGB. The 1R16 depth was 42% while the 1R15 depth was 37%. The reported bobbin amplitude for this indication, approximately 1.7 volts, is more characteristic for the depth report than the 56%TW indication of SGA.

Parent Tube Degradation in Laser Weld Sleeved Tubes

At the 1R15 outage a total of 9 sleeved tubes in SGA and 19 sleeved tubes in SGB were reported with indications in the parent tube adjacent to the sleeve lower hardroll; 100% of the sleeve hardroll regions were inspected with a magnetically biased +Pt coil. The elevation of the indications was fairly consistent, extending from about 1.25 to 1.75" above the sleeve end. The indications were reported as axially oriented, with most exhibiting one indication. As the +Pt examination is being conducted through the sleeve wall, the phase angle responses for estimation of the indication depths cannot be relied upon, nor can flaw amplitudes.

At 1R16, 20 sleeved tubes in SGA and 3 in SGB exhibited similar signals. The range of indication elevations was 0.18 to 2.14" above the hot leg tube entry with an average elevation of 1.1". The 0.18" elevation could be indicative of a potential tube to cladding weld region indication.

All affected sleeved tubes were found to be tubes returned to service by deplugging at the 1R13 outage.

Axial indications within the parent tube adjacent to the sleeve lower hardroll do not represent a challenge to sleeve structural or leakage integrity. The laser welds (upper joint) of all sleeves were found to be intact with no evidence of degradation of the tube, sleeve, or weld. The presence of axial degradation in the parent tube will not significantly detract from the axial load bearing capability of the sleeve joint. In order for the hardroll joint to experience a reduction in axial load bearing capability the tube ID surface would have to expand. As the tube is restrained on the OD by the tubesheet and restrained on the ID by the sleeve, the tube cannot change dimension, thus the joint will remain intact with no apparent loss of axial load bearing capability.

AVB Wear

No tubes were plugged at 1R16 due to AVB wear greater than or equal to the Tech Spec repair limit of 40%TW. The maximum AVB wear depths reported for SGs A, B, and C were 34%, 39%, and 39%.

Mechanisms Not Observed at the BVPS 1R16 Inspection

The following mechanisms were addressed by the initial 1R16 inspection plan but were not observed.

- PWSCC at small radius U-bends
- PWSCC at large radius U-bends
- PWSCC at dented TSP intersections
- Ding ODSCC
- ODSCC coincident with cold leg thinning
- Collapsed sleeves
- Freespan (outside of historic sludge pile) ODSCC

Conclusion

Observed degradation mechanisms for the BVPS 1R16 outage were evaluated using methods consistent with or conservative to the EPRI Tube Integrity Guideline and EPRI In Situ Pressure Testing Guideline. The results of this evaluation show that all observed degradation satisfied the NEI 97-06 structural and leakage integrity performance criteria. The SCC mechanisms observed at 1R16 were bounded by or consistent with the flaw parameter distributions for the 1R15 and 1R14 outages suggesting that the ODSCC growth function at BVPS is consistent with, or reduced compared to previous cycles. The Cycle 16 effective length was 527.7 EFPD, which bounds the Cycle 15 operating period by 42.4 EFPD and the Cycle 14 operating period by 37.7 EFPD. Despite the extended Cycle 16 operating period the observed 1R16 SCC distributions are consistent with past inspection results.

The only mechanism postulated to represent a leakage potential at EOC-16 is axial ODSCC at TSP intersections, which is addressed within the body of this report.

Finally, the EOC-16 operational assessment methodology is judged conservative compared to the observed indications at EOC-16. The projected maximum axial ODSCC in sludge pile amplitude of 0.42 volt bounds the maximum observed amplitude of 0.26 volt, and the projected EOC-16 maximum depth from phase of 95%TW, 72%TW using amplitude bound the observed maximum depths of 84%TW by phase and 54%TW using amplitude. The limiting projected sludge pile ODSCC burst profile of 0.76" and 64.5% average depth significantly bound the EOC-16 flaw profiles from depth profiling. Two indications were reported with flaw lengths from profiling that equal or exceed this length. The length and average depths for these indications was 0.76", 36.65% average depth, and 0.83", 38.5% average depth.

The sludge pile ODSCC indication count for 1R16 was slightly increased compared to 1R15 (76 indications versus 61 indications), however the 1R16 average sludge pile ODSCC amplitude was bounded by the 1R15 average sludge pile ODSCC amplitude.

The axial PWSCC EOC-16 projected amplitude was 2.25 volts, which bounds the EOC-16 observed maximum PWSCC amplitude of 1.06 volts. The projected PWSCC length of 0.55" also bounds the maximum observed EOC-16 PWSCC length of 0.41".

EOC-16 projected AVB wear and cold leg thinning depths also bound the EOC-16 predictions.

Therefore, it can be concluded that the prediction methodology applied for the EOC-16 operational assessment is conservative compared to the observed flaw parameters for EOC-16.

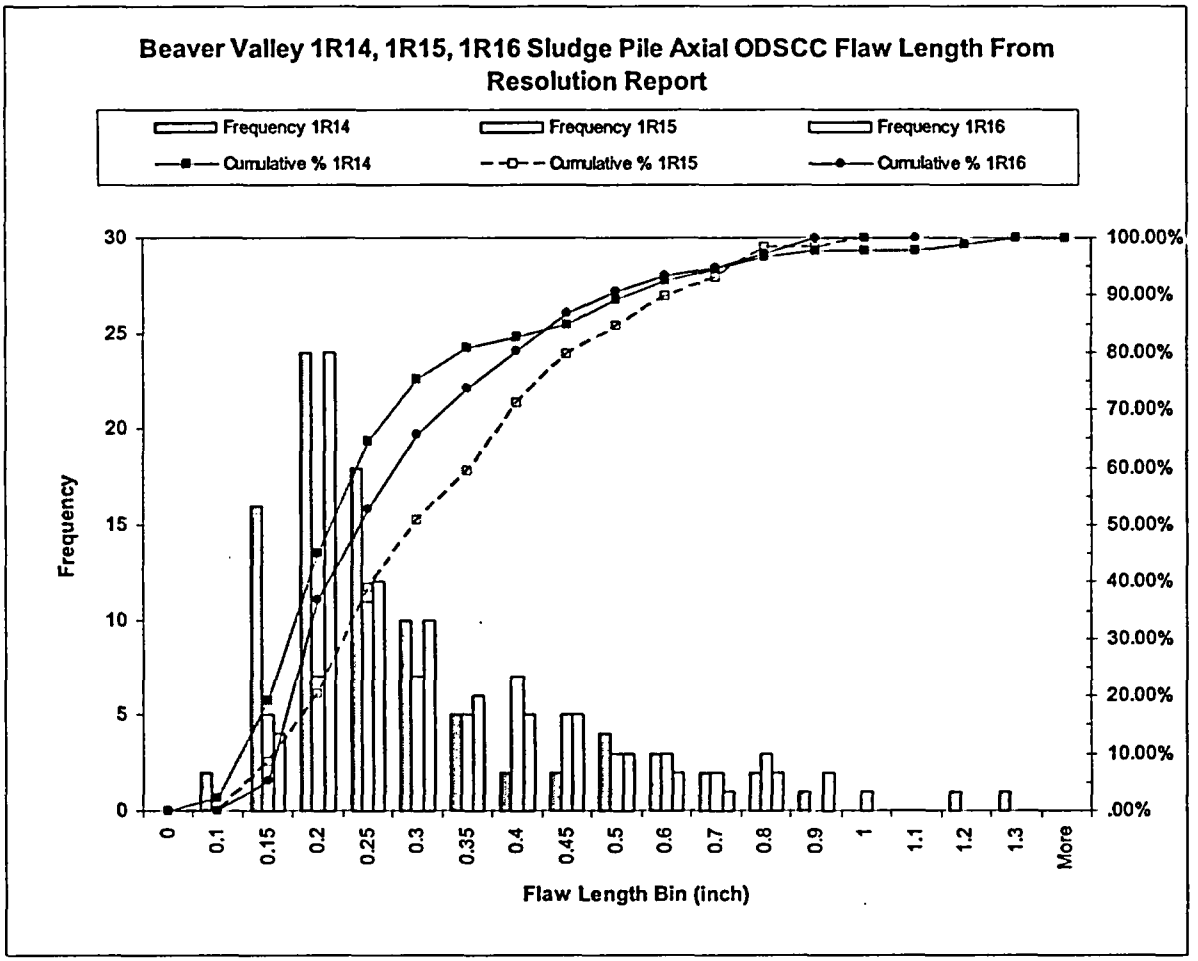

Beaver Valley 1R14, 1R15, 1R16 Sludge Pile Axial ODSCC Flaw Length From Resolution Report
Frequency 1R14
Frequency 1R15
Frequency 1R16
Cumulative % 1R14
Cumulative % 1R15
Cumulative % 1R16
Frequency
30
25
20
15
10
5
0
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
.00%
0
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
More
Flaw Length Bin (inch)

Figure B-1

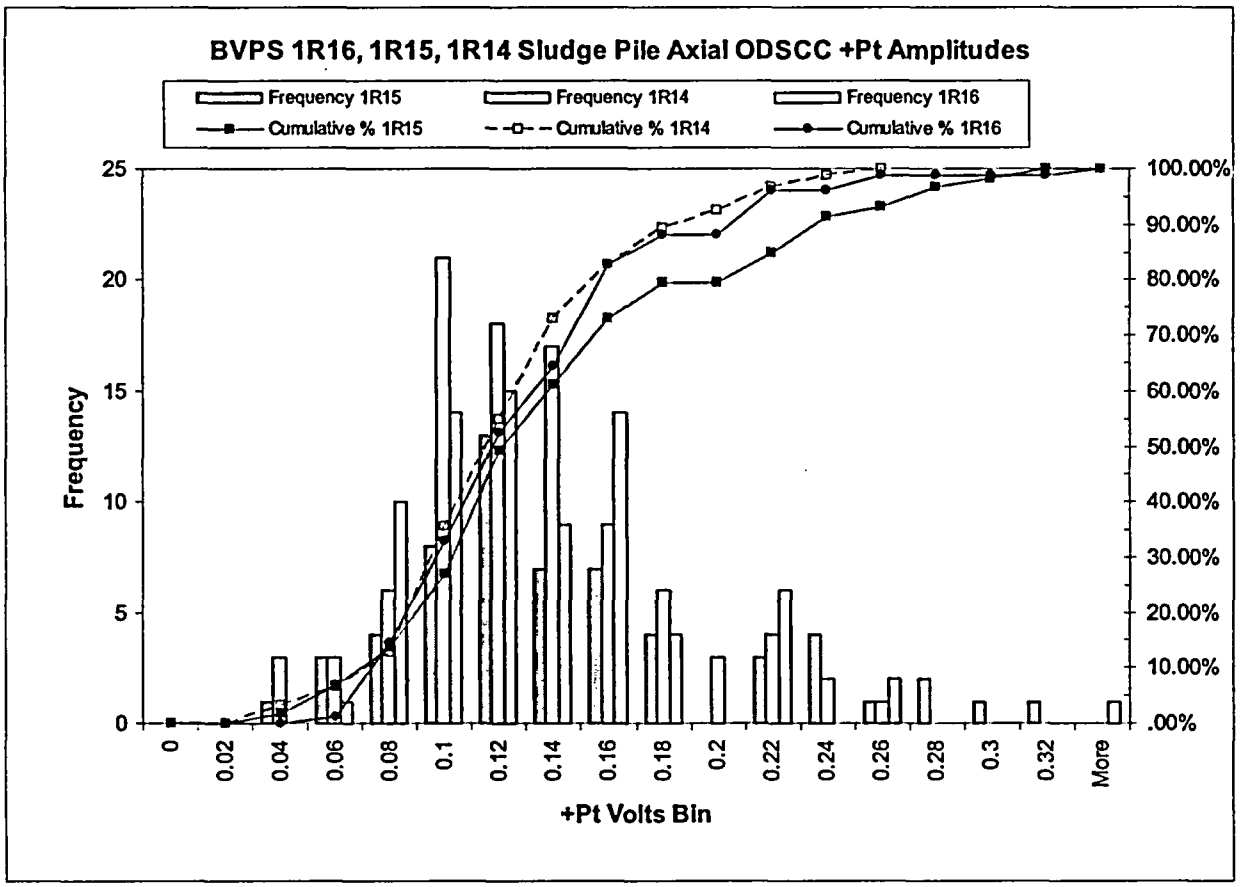

BVPS 1R16, 1R15, 1R14 Sludge Pile Axial ODSCC +Pt Amplitudes
Frequency 1R15
Frequency 1R14
Frequency 1R16
Cumulative % 1R15
Cumulative % 1R14
Cumulative % 1R16
Frequency
25
20
15
10
5
0
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
.00%
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
More
+Pt Volts Bin

Figure B-2