NSD-SGD-1187

# Byron Unit 1

# Interim Plugging Criteria Return to Power Report

# December 1995

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## Interim Plugging Criteria Return to Power Report

### 1.0 Introduction

This report provides the Byron Unit 1 steam generator tube Eddy Current (EC) inspection results at the end of Cycle 7A* together with Steam Line Break (SLB) leak rate and tube burst probability analysis results calculated using the measured voltage data, in support of the implementation of the 3.0 volt Interim Plugging Criteria (IPC). SLB leak rates and tube burst probabilities were calculated considering conditions before and after tube support plate (TSP) locking. Since the EOC-7A results represent completion of a cycle implementing a 1 volt IPC, the reference leak and burst analyses are based on methods which assume that the TSP indications are exposed due to TSP displacement under SLB conditions. The leak and burst analyses based on the assumptions of TSP locking are provided for information as sensitivity analyses. Leak rate and probability of burst (PoB) values calculated with the actual voltage distributions are compared with the corresponding projections for EOC-7A (based on projected indication population using the EOC-6 data). The methodology used in these evaluations is in accordance with previously published Westinghouse reports (References 7.1 and 7.2). Projections of EC bobbin voltage distributions, and leak rate and burst probability analyses based on the 3.0 volt repair criteria for the upcoming Cycle 7B operation will be presented in the 90-day report.

### 2.0 Summary and Conclusions

SLB leak rate and tube burst probability analyses were performed for all four steam generators (SG) based on their actual EOC-7A EC bobbin voltage distributions. During the EOC-6 outage, projections for EOC-7A were performed only for SG-C as it was judged to be the limiting SG since it had the largest growth rate measured and ranked second in the number of indications returned to service. The results based on EOC-7A actual voltage distributions indicate a slightly higher leak rate and burst probability for SG-B in comparison to SG-C, but the absolute differences are small. The EOC-7A projections for SG-C based upon a probability of detection (POD) of 0.6 are very conservative (higher) relative to the results based on the actual EOC-7A voltage distribution by at least a factor of 35. Even for a POD value of unity, the EOC-7A projections are conservative by a factor of 20. The large differences between the projections and actuals are due primarily to reduction in voltage growth, particularly for the large voltage tail of the growth distribution. The leak rate and

* Since this is a mid-cycle inspection, for clarity, the cycle just completed is referred to as Cycle 7A and the upcoming cycle as Cycle 7B

burst probability at the actual EOC-7A voltage distributions for all four SGs, calculated as free span for SLB conditions, are well within the allowable limits.

For the actual EOC-7A bobbin voltage distribution, the largest free span SLB leak rate (applicable prior to TSP locking) is calculated for SG-B and its magnitude is 0.075 gpm. The corresponding burst probability is $1.3 \times 10^{-3}$. These values are much lower than the allowable Cycle 7A SLB leakage limit of 12.5 gpm and the NRC reporting guideline of $10^{-2}$ for the conditional tube burst probability. They are also significantly below the bounding projected leak rate and burst probability for EOC-7A conditions, 2.5 gpm and $1.91 \times 10^{-2}$, predicted for SG-C using the NRC required POD value of 0.6. The corresponding values calculated for SG-B for a locked TSP condition are 0.075 gpm leak rate and a burst probability of less than $4 \times 10^{-6}$ (only cold leg indications contribute to burst). Thus, the results are much lower than IPC requirements, and the EOC-7B projections, to be reported in the 90 day report, can also be expected to meet the requirements. However, the SLB leak rate projections for EOC-7B will be higher than found for the actuals due to the GL 95-05 requirement to use the largest voltage growth found for the last two cycles of operation.

A total of 5005 indications were found in the EOC-7A inspection of which 219 were inspected with a Rotating Pancake Coil (RPC) probe (including a minimum of 20 % of hot leg indications between 1 and 3 volts and all hot leg indications above 3 volts), and 161 were confirmed as flaws. The RPC confirmed indications included 156 above 1.0 volt. SG-B had 1602 bobbin indications, of which 264 were above 1.0 volt, 67 of these were inspected by RPC and 51 were confirmed as flaws. Only one indication was found above 3 volts, 3.17 volts in SG A, and it was confirmed by RPC. No unexpected inspection results were found at the TSP intersections, such as circumferential indications, indications extending outside the TSP or PWSCC at dented TSP intersections.

## 3.0 EOC-7A Inspection Results and Voltage Growth Rates

### 3.1 EOC-7A Inspection Results

In accordance with the IPC guidance provided by the NRC Generic Letter 95-05, the end of Cycle 7A inspection of the Byron Unit 1 steam generators (SG) consisted of a complete, 100% EC bobbin probe full length examination of the tube bundles in all four SGs. A 0.610 inch diameter probe was used for all hot and cold leg TSPs where IPC was applied. Subsequently, RPC examination was performed for a minimum of 20 percent of hot leg indications with an amplitude between 1 and 3 volts, all hot leg indications with an amplitude 3 volts and above, and all cold leg indications with an amplitude above 1 volt. There was only one hot leg indication above 3 volts. It was confirmed as a flaw and plugged. None of the cold leg indications had a bobbin voltage above 1 volt.

In addition, an augmented RPC inspection was performed consistent with the NRC

requirements. All dented intersections with a bobbin voltage greater than 5 volts and a minimum of 20 percent of intersections with a bobbin voltage between 2.5 and 5 volts were inspected with RPC. The augmented RPC inspection also included 8 TSP intersections with mixed residual artifact signals (MRI). There were no RPC flaw indications reported in the augmented inspection.

There was no evidence of any unexpected eddy current results at EOC-7A. There were no RPC circumferential indications at the TSPs, no indications extending outside the TSPs, no RPC indications with potential PWSCC phase angles, no flaw indications at dented TSP intersections at any dent voltage and there was no signal interference from copper deposits. All RPC responses were consistent with that expected for ODSCC at TSP intersections.

A summary of EC indications for all four steam generators is shown on Table 1, which tabulates the number of field bobbin indications, the number of these field bobbin indications that were RPC inspected, the number of RPC confirmed indications, and the number of indications removed from service due to tube repairs. The indications that remain active for Cycle 7B operation is the difference between the observed and the ones removed from service. The steam generator repair list has not yet been finalized pending completion of the sleeving operation. The numbers shown for indications removed from service and indications returned to service are based on a preliminary repair list, and as such, they may be revised.

Overall, the combined data for all four steam generators of Byron Unit 1 shows that:

- Out of a total of 5005 indications identified during the inspection, a total of 219 were RPC inspected.

- Of the 219 RPC inspected, a total of 161 were RPC confirmed.

- Based on the preliminary repair list, it is expected that about 525 indications would be removed from service. Consistent with the new 3 volt IPC, RPC confirmed hot leg indications with bobbin an amplitude of less than or equal 3.0 volts and RPC confirmed cold leg indications less than or equal to 1 volt are not considered for removal from service.

A review of Table 1 indicates that although a few more indications were found in SG-B (1602) than in SG-C (1595), more indications (a quantity of 1546, with 244 indications above 1.0 volt) would be returned to service in SG-C, per preliminary repair list, thereby it potentially will be the limiting SG at EOC-7B. However, it is noted that SG-A had the largest indication (3.17 volts) found in the EOC-7A inspection. Figure 1 shows the actual bobbin voltage distribution determined from the EOC-7A EC inspection; Figure 2 shows the population distribution of those EOC-7A indications removed from service due to tube repairs; Figure 3 shows the indications which could be returned to service for Cycle 7B, per

preliminary tube repair list. Of the 525 indications to be removed from service, only 21 indications are of the nature requiring tube repairs and the rest are in tubes plugged for degradation mechanisms other than ODSCC at TSP's .

### 3.2 Voltage Growth Rates

Table 2 shows the cumulative probability distribution function for growth rate of each Byron Unit 1 steam generator during the last two operating periods (Cycles 6 and 7A). The growth rates are presented on an EFPY basis to account for the difference in the length of two operating periods. Figure 4 provides a comparison of the composite voltage growth from all four steam generators for the two operating periods. For Cycle 7A operation, SG-B has a slightly larger average voltage growth among the four steam generators, and it also has the indication with the largest voltage growth.

Chemical cleaning of the Byron Unit 1 steam generators was performed during the EOC-6 outage, so it is of interest to compare the growth rates for Cycle 6 and 7A. Overall, the growth rates during Cycle 7A are slightly under those observed for Cycle 6. The average growth rate for all four SGs combined was 0.269 volt /EFPY during Cycle 6 versus 0.235 volt /EFPY for Cycle 7A. While there were 10 indications among all four SGs with a growth rate above 2 volts in Cycle 6, only two such indications were found for Cycle 7A. The highest growth rate for Cycle 6 was 7.8 volt /EFPY compared to 2.5 volt /EFPY for Cycle 7A.

### 3.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 7A voltage distributions in the Monte Carlo analyses for leak rate and burst probability are the same as those described in the Braidwood Unit 1 IPC report of Reference 7.1. The probe wear standard used in the analyses has a standard deviation of 7.0 % about a mean of zero and a cutoff at 15 % for voltage response variability, which is consistent with the alternate probe wear measurement approach used during the EOC-7A inspection. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cutoff.

## 4.0 Database Applied for IPC Correlations

The database used for the IPC correlations that are applied in the analyses of this report are an updated version of the database documented in Reference 7.2. South Texas pulled tube data have been added to the IPC database. The updated database is in compliance with the NRC GL 95-05 guidelines for application of leak rate versus voltage correlations and for removal of data outliers in the 3/4 inch tubing burst and leak rate correlations.

## 5.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for actual voltage distributions. The methodology used complies with the Byron Unit 1 SER and is described in Reference 7.1, and also in the Westinghouse generic methods report of Reference 7.2.

Monte Carlo analyses for leak rates and tube burst probabilities for the actual distributions include NDE uncertainties. Based on the 3/4" diameter tubing database, the NRC requirement that the p value obtained from the regression analysis be less than or equal to 5% to apply the SLB leak rate versus voltage correlation is satisfied and the correlation is applied for the leak rate analyses of this report.

SLB leak rates and tube burst probabilities are calculated considering conditions before and after tube support plate (TSP) locking. When TSP's are locked with tube expansion, indications in the hot leg side are restrained from bursting so the burst probability calculations are based only on indications found on the cold side. Since only a small fraction of the indication population is on the cold leg side, the burst probabilities are expected to be substantially smaller than those estimated with the usual IPC/APC methodology (which includes the entire indication population). Leak rate analysis include indications restrained from burst (IRBs) based on a 6.0 gpm leak rate for IRBs. Leak rates and PoB calculated by both methods using the actual voltage distributions are compared with the corresponding prior projections for EOC-7A.

## 6.0 SLB Leak Rate and Tube Burst Probability for EOC-7A

Using the methodology described above, analyses were performed to calculate EOC-7A SLB leak rate and tube burst probabilities for the actual bobbin voltage distribution presented in Table 1. The analyses considered conditions before and after TSP locking. The results of Monte Carlo calculations for Cycle 7A are summarized on Table 3. The free span analyses (appropriate prior to TSP locking) are the reference analyses for Cycle 7A and their results are to be compared with allowable limits. Comparison of the EOC-7A actuals with the corresponding predictions indicates that:

a) SG-C was predicted to be the most limiting steam generator for EOC-7A based on an EOC-7A voltage distribution projection performed during EOC-6 inspection.

b) SG-B was determined to have the highest tube leak rate and PoB numbers based on actual EC bobbin measurements for EOC-7A, although the absolute differences in the results for SG-B and SG-C are small.

c) The leak rate and PoB predictions from the EOC-6 inspection (based on projected indication population distribution) for SG-C are very conservative compared to actual leak and PoB values for all four SGs based on EC bobbin measurements for EOC-7A (by a factor of at least 35). The large differences between projections and actuals are attributable to a reduction in voltage growth. Figure 5 shows the actual and projected EOC-7A bobbin distributions used in the leak rate and burst analyses for SG-C. The projected indication population based on EPRI POD being greater than the measured population above 0.9 volt indicates that the actual growth rates in Cycle 7A were below the growth rates assumed for projections (Cycle 6 rates). The use of a constant POD of 0.6, per the GL 95-05 requirement, results in further overestimation of indication population in higher voltage bins, and consequently, introduces additional conservatism in the results.

d) The leak rate and PoB predictions for all four SG's based EOC-7A bobbin measurements are well within the allowable limits.

e) With TSP's locked, tube burst probability decreases by more than two orders of magnitude.

f) The effect of IRBs on the SLB leak rate compared to free span analysis is negligible due to the low free span PoB for the actual distributions.

In summary, the free span SLB leak rate (0.064 gpm) and tube burst probability ($5.33 \times 10^{-4}$) calculated using the actual EOC-7A bobbin voltage distribution for SG-C are far below the corresponding projections assuming a voltage frequency based on the NRC SER endorsed probability of detection of 0.6. The limiting leak rate (0.075 gpm) and Pob ($1.3 \times 10^{-3}$) values were calculated for SG-B, and they are slightly higher than those calculated for SG-C. The results for all four SGs are much lower than the allowable Cycle 7A SLB leakage limit of 12.5 gpm and the NRC reporting guideline of $10^{-2}$ for the tube burst probability. Thus, the results meet the IPC requirement for continued operations for at least 90 days. Predictions for EOC-7B to be presented in the 90 day report will justify continued operation beyond 90 days. The major impact of restraining indications on the hot leg side from bursting is to decrease tube burst probability by over two orders of magnitude.

## 7.0 REFERENCES


7.1 WCAP-14046, Rev. 1, "Braidwood Unit 1 Technical Support for Cycle 5 Steam Generator Interim Plugging Criteria", Westinghouse Nuclear Service Division.

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

7.3 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.

7.4 WCAP-14273, "Technical Support for Alternate Plugging Criteria with Tube Expansion at Tube Support Plate Intersections for Braidwood-1 and Byron-1 Model D Steam Generators," Westinghouse Nuclear Service Division, February 1995.

## Table 1 ( Sheet 1 of 2)
## Byron Unit -1 November 1995 Outage
## Summary of Inspection and Repair For Tubes in Service During Cycle 7A

| Voltage Bin | Steam Generator A | | | | | Steam Generator B | | | | | Steam Generator C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In-Service During Cycle 7A | | | | BOC - 7B | In-Service During Cycle 7A | | | | BOC - 7B | In-Service During Cycle 7A | | | | BOC - 7B |
| | Field Bobbin Indications | RPC Inspected | RPC Confirmed | Indications Repaired | All Indications Returned to Service | Field Bobbin Indications | RPC Inspected | RPC Confirmed | Indications Repaired | All Indications Returned to Service | Field Bobbin Indications | RPC Inspected | RPC Confirmed | Indications Repaired | All Indications Returned to Service |
| 0.2 | 6 | 0 | 0 | 0 | 6 | 8 | 0 | 0 | 0 | 8 | 13 | 1 | 0 | 0 | 13 |
| 0.3 | 47 | 0 | 0 | 4 | 43 | 95 | 2 | 1 | 2 | 93 | 71 | 0 | 0 | 0 | 71 |
| 0.4 | 132 | 3 | 0 | 13 | 119 | 199 | 1 | 0 | 10 | 189 | 157 | 3 | 0 | 3 | 154 |
| 0.5 | 141 | 3 | 1 | 11 | 130 | 209 | 2 | 1 | 16 | 193 | 251 | 1 | 1 | 3 | 248 |
| 0.6 | 149 | 2 | 0 | 15 | 134 | 221 | 4 | 2 | 13 | 208 | 225 | 7 | 3 | 5 | 220 |
| 0.7 | 98 | 1 | 0 | 8 | 90 | 216 | 2 | 1 | 16 | 200 | 214 | 3 | 1 | 8 | 206 |
| 0.8 | 86 | 2 | 0 | 12 | 74 | 171 | 1 | 0 | 15 | 156 | 171 | 1 | 0 | 3 | 168 |
| 0.9 | 79 | 1 | 1 | 8 | 71 | 124 | 3 | 1 | 6 | 118 | 129 | 1 | 1 | 6 | 123 |
| 1 | 50 | 0 | 0 | 6 | 44 | 95 | 1 | 1 | 2 | 93 | 101 | 3 | 1 | 2 | 99 |
| 1.1 | 32 | 1 | 1 | 5 | 27 | 72 | 8 | 6 | 14 | 58 | 78 | 6 | 2 | 3 | 75 |
| 1.2 | 37 | 1 | 1 | 4 | 33 | 56 | 8 | 6 | 17 | 39 | 54 | 0 | 0 | 1 | 53 |
| 1.3 | 22 | 2 | 2 | 1 | 21 | 39 | 8 | 7 | 13 | 26 | 39 | 4 | 4 | 1 | 38 |
| 1.4 | 11 | 3 | 2 | 0 | 11 | 16 | 3 | 3 | 4 | 12 | 35 | 9 | 7 | 0 | 35 |
| 1.5 | 7 | 3 | 3 | 1 | 6 | 26 | 2 | 2 | 8 | 18 | 14 | 8 | 8 | 0 | 14 |
| 1.6 | 10 | 7 | 7 | 0 | 10 | 15 | 6 | 5 | 7 | 8 | 14 | 9 | 9 | 5 | 9 |
| 1.7 | 3 | 1 | 0 | 0 | 3 | 5 | 1 | 1 | 1 | 4 | 11 | 7 | 7 | 2 | 9 |
| 1.8 | 4 | 2 | 2 | 1 | 3 | 11 | 0 | 0 | 1 | 10 | 5 | 2 | 2 | 1 | 4 |
| 1.9 | 4 | 2 | 2 | 2 | 2 | 9 | 1 | 1 | 4 | 5 | 2 | 2 | 2 | 1 | 1 |
| 2 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 3 | 0 |
| 2.1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 2 | 2 | 2 | 0 | 2 |
| 2.2 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 1 | 3 | 2 | 1 | 1 | 0 | 2 |
| 2.3 | 2 | 2 | 2 | 0 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2.4 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 2 | 2 | 1 | 1 |
| 3 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 922 | 38 | 26 | 92 | 830 | 1602 | 67 | 51 | 153 | 1449 | 1595 | 76 | 57 | 49 | 1546 |
| >1V | 134 | 26 | 24 | 15 | 119 | 264 | 51 | 44 | 73 | 191 | 263 | 56 | 50 | 19 | 244 |

**Table 1 ( Sheet 2 of 2)**
**Byron Unit -1 November 1995 Outage**
**Summary of Inspection and Repair For Tubes in Service During Cycle 7A**

| Voltage Bin | Steam Generator D | | | | | Composite of All 4 SGs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | In-Service During Cycle 7A | | | | BOC - 7B | In-Service During Cycle 7A | | | | BOC - 7B |
| | Field Bobbin Indications | RPC Inspected | RPC Confirmed | Indications Repaired | All Indications Returned to Service | Field Bobbin Indications | RPC Inspected | RPC Confirmed | Indications Repaired | All Indications Returned to Service |
| 0.2 | 9 | 1 | 0 | 4 | 5 | 36 | 2 | 0 | 4 | 32 |
| 0.3 | 88 | 0 | 0 | 25 | 63 | 301 | 2 | 1 | 31 | 270 |
| 0.4 | 144 | 4 | 1 | 31 | 113 | 632 | 11 | 1 | 57 | 575 |
| 0.5 | 121 | 0 | 0 | 23 | 98 | 722 | 6 | 3 | 53 | 669 |
| 0.6 | 126 | 3 | 1 | 33 | 93 | 721 | 16 | 6 | 66 | 655 |
| 0.7 | 109 | 3 | 3 | 35 | 74 | 637 | 9 | 5 | 67 | 570 |
| 0.8 | 70 | 2 | 2 | 21 | 49 | 498 | 6 | 2 | 51 | 447 |
| 0.9 | 62 | 0 | 0 | 20 | 42 | 394 | 5 | 3 | 40 | 354 |
| 1 | 43 | 2 | 0 | 13 | 30 | 289 | 6 | 2 | 23 | 266 |
| 1.1 | 30 | 2 | 2 | 7 | 23 | 212 | 17 | 11 | 29 | 183 |
| 1.2 | 20 | 1 | 1 | 3 | 17 | 167 | 10 | 8 | 25 | 142 |
| 1.3 | 15 | 1 | 1 | 1 | 14 | 115 | 15 | 14 | 16 | 99 |
| 1.4 | 13 | 4 | 3 | 3 | 10 | 75 | 19 | 15 | 7 | 68 |
| 1.5 | 7 | 3 | 3 | 2 | 5 | 54 | 16 | 16 | 11 | 43 |
| 1.6 | 5 | 2 | 2 | 1 | 4 | 44 | 24 | 23 | 13 | 31 |
| 1.7 | 9 | 1 | 0 | 3 | 6 | 28 | 10 | 8 | 6 | 22 |
| 1.8 | 5 | 0 | 0 | 3 | 2 | 25 | 4 | 4 | 6 | 19 |
| 1.9 | 0 | 0 | 0 | 0 | 0 | 15 | 5 | 5 | 7 | 8 |
| 2 | 3 | 2 | 2 | 0 | 3 | 9 | 6 | 6 | 4 | 5 |
| 2.1 | 1 | 1 | 1 | 0 | 1 | 5 | 5 | 4 | 0 | 5 |
| 2.2 | 1 | 1 | 1 | 1 | 0 | 7 | 6 | 6 | 2 | 5 |
| 2.3 | 1 | 1 | 0 | 0 | 1 | 4 | 4 | 3 | 0 | 4 |
| 2.4 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 2 |
| 2.5 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 |
| 2.6 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 2.7 | 1 | 1 | 1 | 1 | 0 | 4 | 4 | 4 | 2 | 2 |
| 3 | 2 | 2 | 2 | 1 | 1 | 4 | 4 | 4 | 2 | 2 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| Total | 886 | 38 | 27 | 231 | 655 | 5005 | 219 | 161 | 525 | 4480 |
| >1V | 114 | 23 | 20 | 26 | 88 | 775 | 156 | 138 | 133 | 642 |

# Table 2
## Byron Unit 1 November 1995
## Signal Growth Statistics For Cycle 7A on an EFPY Basis

| Delta Volts | Steam Generator A | | | Steam Generator B | | | Steam Generator C | | | Steam Generator D | | | Cumulative | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cycle 6 | Cycle 7A | | Cycle 6 | Cycle 7A | | Cycle 6 | Cycle 7A | | Cycle 6 | Cycle 7A | | Cycle 6 | Cycle 7A | |
| | CPDF | No. of Obs | CPDF | CPDF | No. of Obs | CPDF | CPDF | No. of Obs | CPDF | CPDF | No. of Obs | CPDF | CPDF | No. of Obs | CPDF |
| -0.5 | 0.001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| -0.4 | 0.004 | 0 | 0 | 0 | 1 | 0.0006 | 0 | 0 | 0 | 0.000 | 0 | 0 | 0.001 | 1 | 0.0002 |
| -0.3 | 0.004 | 0 | 0 | 0.005 | 1 | 0.0012 | 0.009 | 0 | 0 | 0.000 | 1 | 0.0011 | 0.005 | 2 | 0.0006 |
| -0.2 | 0.011 | 2 | 0.002 | 0.035 | 6 | 0.0050 | 0.027 | 5 | 0.003 | 0.017 | 1 | 0.0023 | 0.024 | 14 | 0.0034 |
| -0.1 | 0.026 | 15 | 0.018 | 0.081 | 25 | 0.0206 | 0.072 | 29 | 0.021 | 0.052 | 12 | 0.0158 | 0.060 | 81 | 0.0196 |
| 0 | 0.057 | 58 | 0.081 | 0.170 | 151 | 0.1149 | 0.152 | 166 | 0.125 | 0.124 | 70 | 0.0948 | 0.128 | 445 | 0.1085 |
| 0.1 | 0.196 | 206 | 0.305 | 0.350 | 409 | 0.3702 | 0.297 | 407 | 0.381 | 0.339 | 205 | 0.3262 | 0.293 | 1227 | 0.3536 |
| 0.2 | 0.399 | 181 | 0.501 | 0.546 | 327 | 0.5743 | 0.443 | 291 | 0.563 | 0.537 | 183 | 0.5327 | 0.476 | 982 | 0.5499 |
| 0.3 | 0.590 | 180 | 0.696 | 0.660 | 248 | 0.7291 | 0.591 | 244 | 0.716 | 0.739 | 141 | 0.6919 | 0.633 | 813 | 0.7123 |
| 0.4 | 0.726 | 124 | 0.831 | 0.770 | 150 | 0.8227 | 0.720 | 183 | 0.831 | 0.846 | 87 | 0.7901 | 0.755 | 544 | 0.8210 |
| 0.5 | 0.805 | 61 | 0.897 | 0.868 | 84 | 0.8752 | 0.825 | 85 | 0.884 | 0.907 | 56 | 0.8533 | 0.845 | 286 | 0.8781 |
| 0.6 | 0.874 | 38 | 0.938 | 0.923 | 69 | 0.9182 | 0.891 | 64 | 0.924 | 0.930 | 52 | 0.9120 | 0.902 | 223 | 0.9227 |
| 0.7 | 0.928 | 21 | 0.961 | 0.955 | 41 | 0.9438 | 0.924 | 43 | 0.951 | 0.961 | 25 | 0.9402 | 0.940 | 130 | 0.9487 |
| 0.8 | 0.951 | 13 | 0.975 | 0.974 | 20 | 0.9563 | 0.945 | 27 | 0.968 | 0.987 | 16 | 0.9582 | 0.962 | 76 | 0.9638 |
| 0.9 | 0.969 | 12 | 0.988 | 0.984 | 19 | 0.9682 | 0.969 | 20 | 0.981 | 0.989 | 8 | 0.9673 | 0.976 | 59 | 0.9756 |
| 1 | 0.976 | 4 | 0.992 | 0.988 | 15 | 0.9775 | 0.978 | 8 | 0.986 | 0.993 | 10 | 0.9786 | 0.983 | 37 | 0.9830 |
| 1.1 | 0.979 | 0 | 0.992 | 0.991 | 12 | 0.9850 | 0.980 | 7 | 0.990 | 0.993 | 5 | 0.9842 | 0.985 | 24 | 0.9878 |
| 1.2 | 0.984 | 3 | 0.996 | 0.993 | 4 | 0.9875 | 0.983 | 6 | 0.994 | 0.996 | 3 | 0.9876 | 0.988 | 16 | 0.9910 |
| 1.3 | 0.985 | 1 | 0.997 | 0.995 | 9 | 0.9931 | 0.986 | 5 | 0.997 | 0.996 | 5 | 0.9932 | 0.990 | 20 | 0.9950 |
| 1.4 | 0.988 | 1 | 0.998 | 0.995 | 3 | 0.9950 | 0.991 | 1 | 0.997 | 0.996 | 1 | 0.9944 | 0.992 | 6 | 0.9962 |
| 1.5 | 0.991 | 1 | 0.999 | 0.996 | 3 | 0.9969 | 0.992 | 1 | 0.998 | 0.996 | 1 | 0.9955 | 0.993 | 6 | 0.9974 |
| 1.6 | 0.994 | 0 | 0.999 | 0.997 | 0 | 0.9969 | 0.993 | 1 | 0.999 | 0.996 | 0 | 0.9955 | 0.995 | 1 | 0.9976 |
| 1.7 | 0.995 | 1 | 1 | 0.997 | 1 | 0.9975 | 0.994 | 0 | 0.999 | 0.996 | 0 | 0.9955 | 0.995 | 2 | 0.9980 |
| 1.8 | 0.995 | | | 0.997 | 2 | 0.9988 | 0.997 | 1 | 0.999 | 0.998 | 2 | 0.9977 | 0.996 | 5 | 0.9990 |
| 1.9 | 0.995 | | | 0.997 | 0 | 0.9988 | 0.997 | 0 | 0.999 | 0.998 | 0 | 0.9977 | 0.996 | 0 | 0.9990 |
| 2 | 0.995 | | | 0.998 | 0 | 0.9988 | 0.997 | 0 | 0.999 | 0.998 | 1 | 0.9989 | 0.997 | 1 | 0.9992 |
| 2.1 | 0.995 | | | 0.998 | 1 | 0.9994 | 0.997 | 1 | 1 | 0.998 | 0 | 0.9989 | 0.997 | 2 | 0.9996 |
| 2.2 | 0.995 | | | 0.998 | 0 | 0.9994 | 0.997 | | | 0.998 | 1 | 1 | 0.997 | 1 | 0.9998 |
| 2.3 | 0.996 | | | 0.998 | 0 | 0.9994 | 0.999 | | | 0.998 | | | 0.997 | 0 | 0.9998 |
| 2.4 | 0.996 | | | 0.999 | 0 | 0.9994 | 0.999 | | | 0.998 | | | 0.998 | 0 | 0.9998 |
| 2.5 | 0.995 | | | 0.998 | 1 | 1 | 0.997 | | | 0.998 | | | 0.998 | 1 | 1 |
| 2.9 | 0.996 | | | 1 | | | 0.999 | | | 0.998 | | | 0.998 | | |
| 3 | 0.996 | | | | | | 0.999 | | | 1 | | | 0.999 | | |
| 4.3 | 0.998 | | | | | | 0.999 | | | | | | 0.999 | | |
| 4.7 | 0.999 | | | | | | 0.999 | | | | | | 0.999 | | |
| 5.3 | 1 | | | | | | 1 | | | | | | 0.9997 | | |
| 7.8 | | | | | | | 1 | | | | | | 1 | | |
| Total | | 922 | | | 1602 | | | 1595 | | | 886 | | | 5005 | |

## Table 3

### Byron Unit 1 1995 EOC- 7A Outage
### Summary of Calculations of Tube Leak Rate and Burst Probability
### Based on Actual Bobbin Voltage - 250k Simulations

| Steam Generator | | POD | Number of Indications | Max. Volts[1] | Burst Probability | | SLB Leak Rate gpm |
|---|---|---|---|---|---|---|---|
| | | | | | 1 Tube | 2 Tubes | |
| EOC - 7A PROJECTIONS FROM EOC-6[2] | | | | | | | |
| C | | 0.6 | 1215 | 11.5 | $1.91\times10^{-2}$ | $1.66\times10^{-4}$ | 2.50 |
| C | | EPRI | 856 | 6.7 | $5.17\times10^{-3}$ | $1.95\times10^{-5}$ | 1.00 |
| C | | POPCD | 977 | 6.8 | $5.91\times10^{-3}$ | $5.19\times10^{-6}$ | 1.20 |
| C | | 1 | 616 | 6.5 | $3.26\times10^{-3}$ | $1.20\times10^{-4}$ | 0.52 |
| EOC - 7A ACTUAL (Free Span - With Displaced Tube Support Plates) | | | | | | | |
| A | | 1 | 922 | 3.5 | $1.07\times10^{-3}$ | $< 4\times10^{-6}$ | 0.060 |
| B | | 1 | 1602 | 3.5 | $1.30\times10^{-3}$ | $< 4\times10^{-6}$ | 0.075 |
| C | | 1 | 1595 | 3.2 | $5.33\times10^{-4}$ | $< 4\times10^{-6}$ | 0.064 |
| D | | 1 | 886 | 3.5 | $6.49\times10^{-4}$ | $< 4\times10^{-6}$ | 0.056 |
| EOC - 7A ACTUAL (Tube Support Plates Assumed Locked) | | | | | | | |
| A | Hot Side | 1 | 919 | 3.5 | Negligible[3] | Negligible[3] | 0.060 |
| | Cold Side | 1 | 3 | 0.7 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | $1\times10^{-4}$ |
| | Combined | - | 922 | 3.5 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | 0.06 |
| B | Hot Side | 1 | 1599 | 3.5 | Negligible[3] | Negligible[3] | 0.075 |
| | Cold Side | 1 | 3 | 1.3 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | $1\times10^{-4}$ |
| | Combined | - | 1602 | 3.5 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | 0.075 |
| C | Hot Side | 1 | 1594 | 3.2 | Negligible[3] | Negligible[3] | 0.064 |
| | Cold Side | 1 | 1 | 0.8 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | $1\times10^{-4}$ |
| | Combined | - | 1595 | 3.2 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | 0.064 |
| D | Hot Side | 1 | 885 | 3.5 | Negligible[3] | Negligible[3] | 0.056 |
| | Cold Side | 1 | 1 | 0.4 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | $1\times10^{-4}$ |
| | Combined | - | 886 | 3.5 | $< 4\times10^{-6}$ | $< 4\times10^{-6}$ | 0.056 |

Notes:

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

2 Based on a projected mid-cycle 7 length of 298.5 EFPD (Actual Cycle 7A duration is 317.4 EFPD).

3 Below $10^{-10}$ (Reference 7-4)

**Figure 1**
**Byron Unit -1 October 1995 Outage**
**Bobbin Voltage Distributions for Tubes in Service During Cycle 7A**

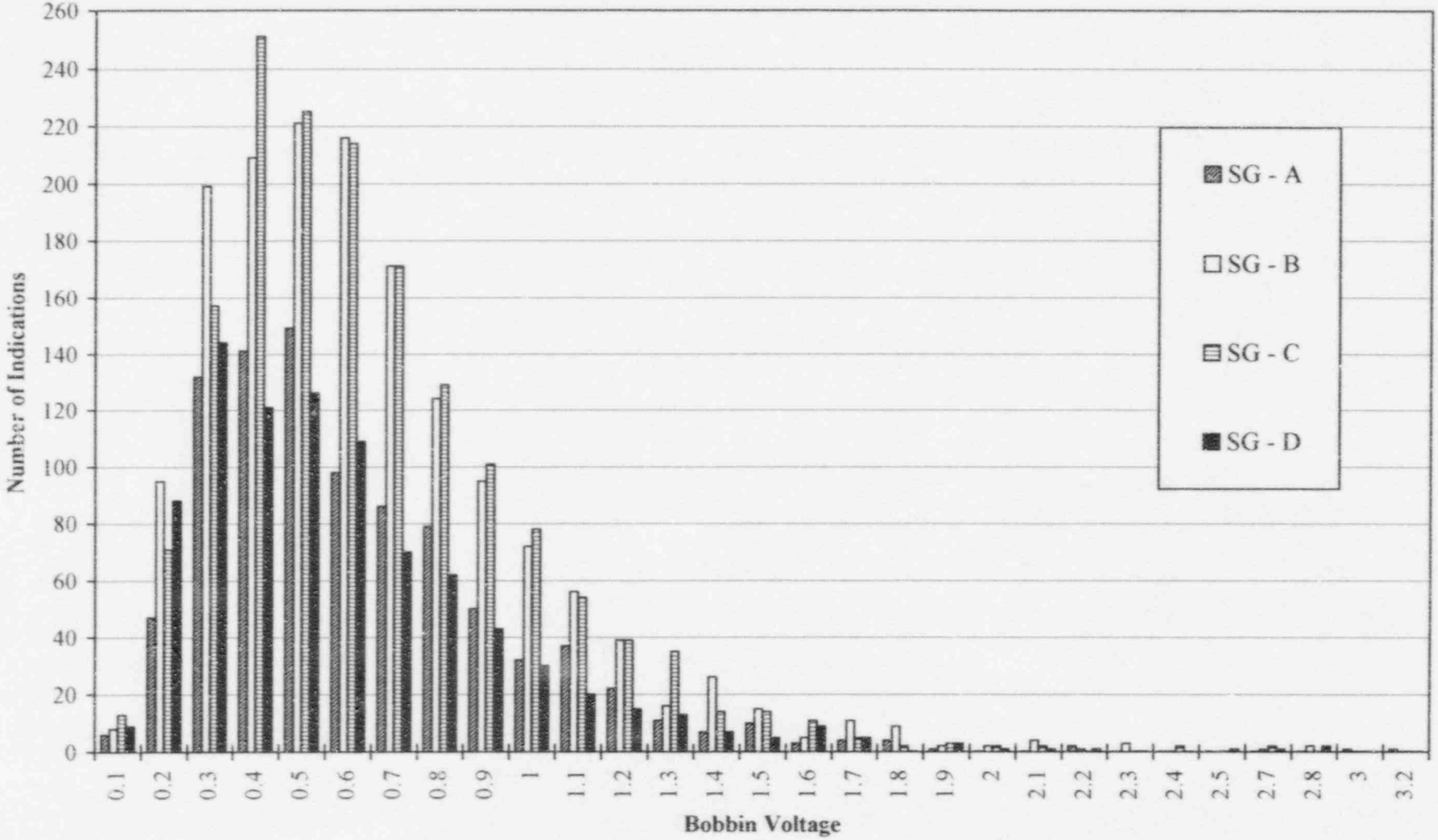


**Figure 2**
**Byron Unit -1 November 1995 Outage**
**Bobbin Voltage Distribution for Tubes Plugged After Cycle 7A Service**

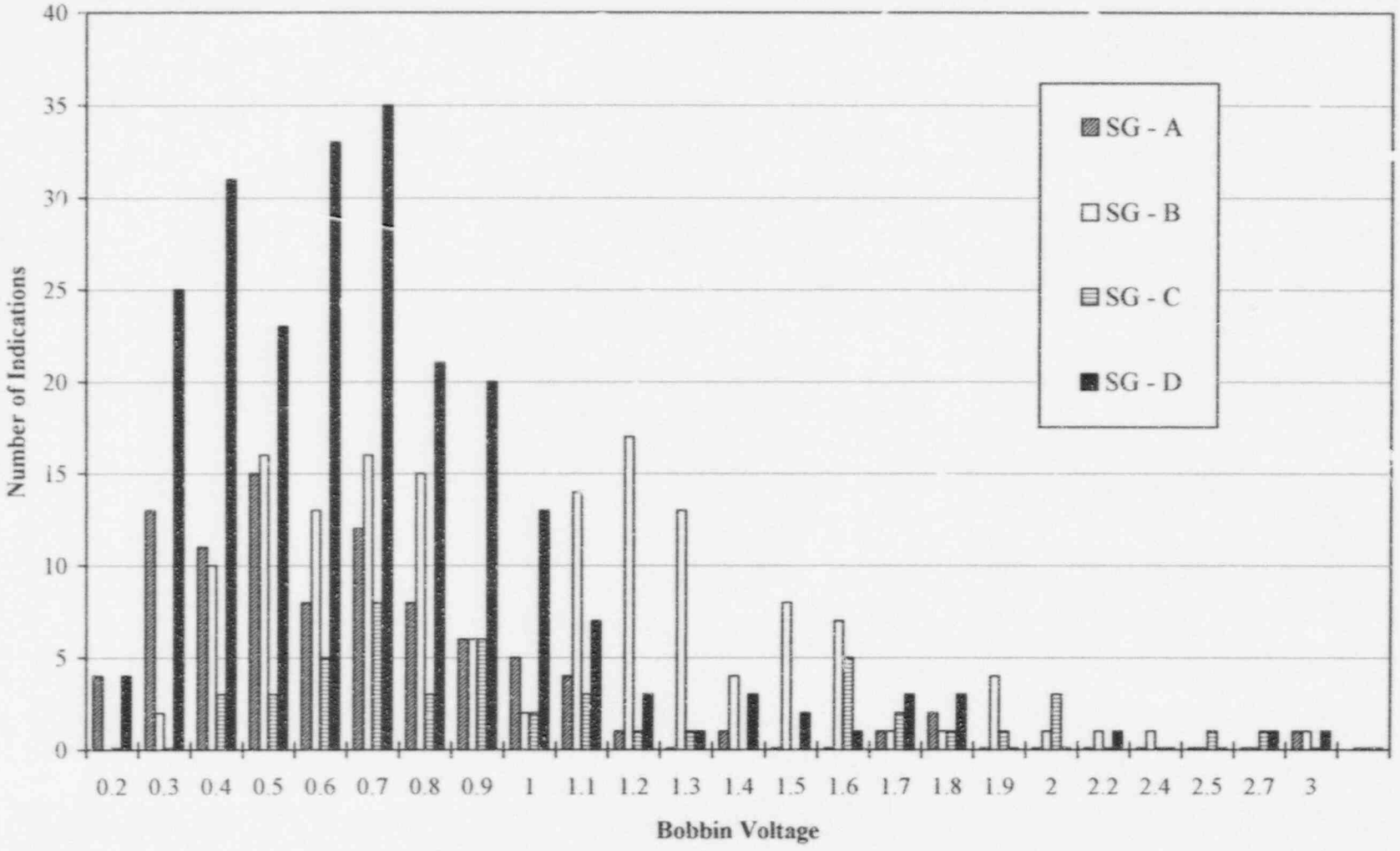


**Figure 3**
**Byron Unit -1 November 1995 Outage**
**Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 7B**

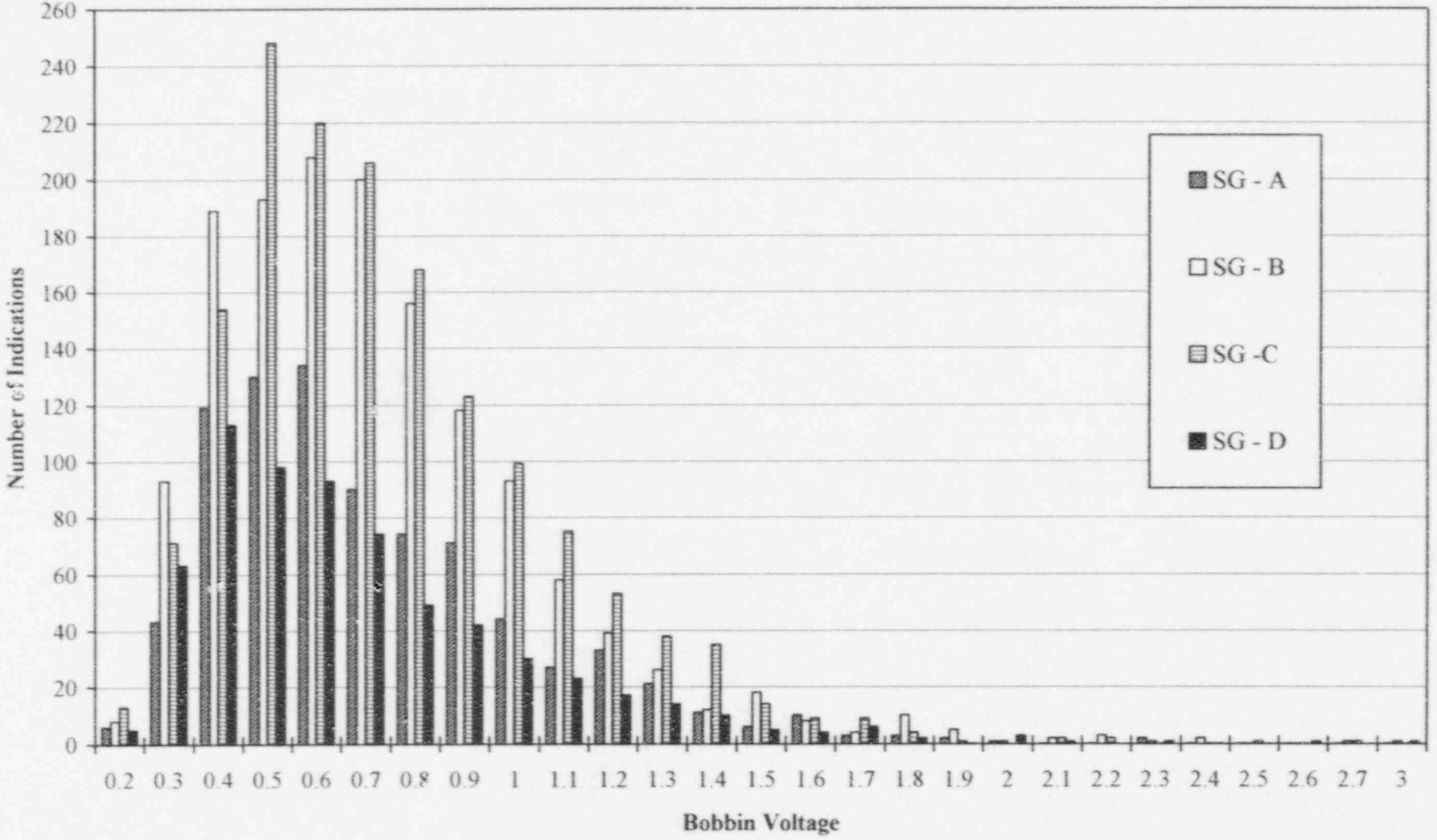
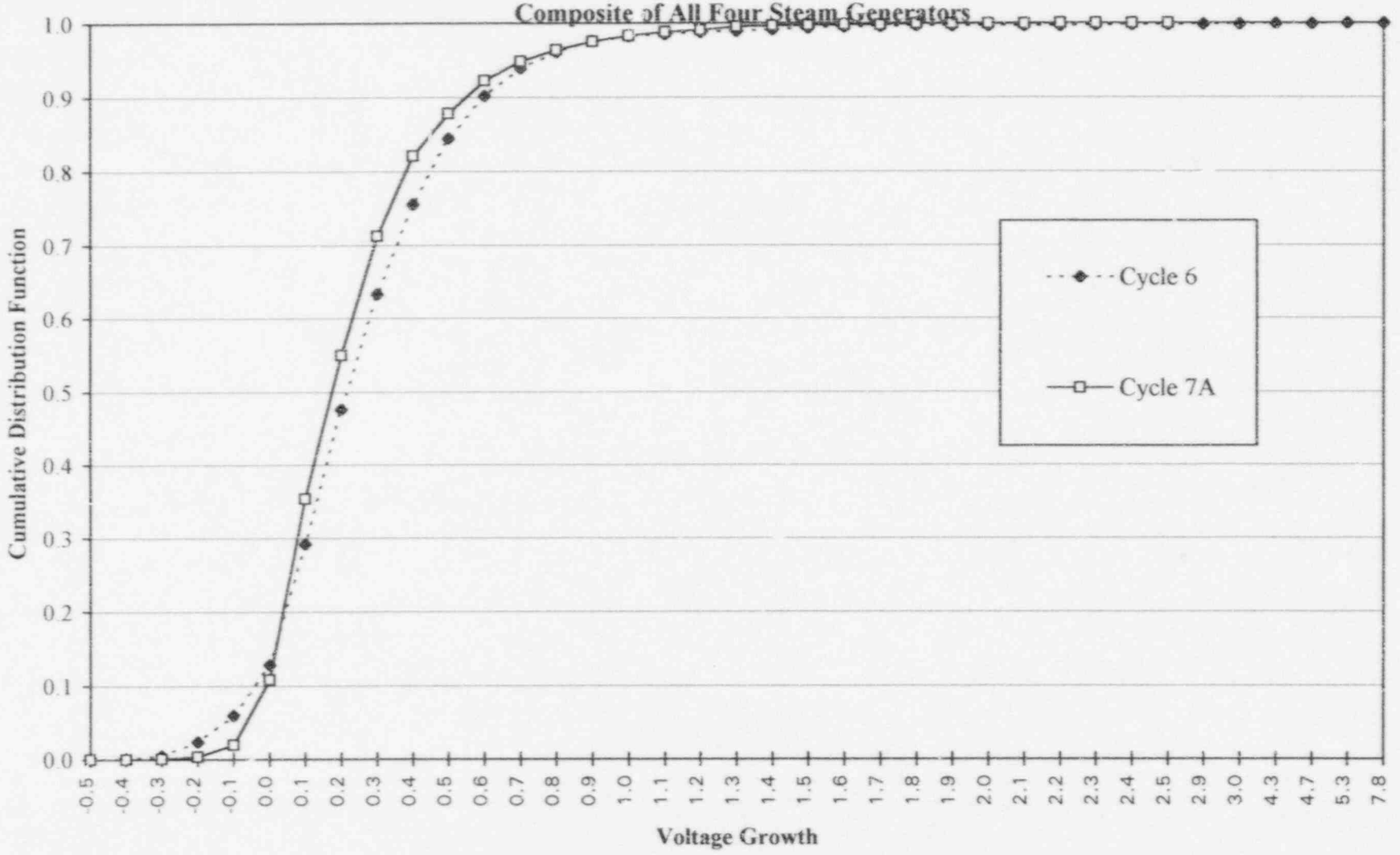


**Figure 4**
**Byrond Unit -1**
**Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis**
**Composite of All Four Steam Generators**




ME2118.XLSFig 4

**Figure 5**
**Byron Unit -1 November 1995 Outage**
**Bobbin Voltage Distributions for Steam Generator C at EOC-7A**