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October 11, 2016
L-16-241

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT:
Beaver Valley Power Station, Unit No. 2
Docket No. 50-412, License No. NPF-73
Updated Steam Generator Inspection Report – Fall 2015 Refueling Outage (CAC No. MF7472)

By letter dated January 22, 2016 (Accession No. ML16025A168) FirstEnergy Nuclear Operating Company (FENOC) submitted a report summarizing the results of the 2015 steam generator tube inspections for Beaver Valley Power Station, Unit No. 2. The Nuclear Regulatory Commission (NRC) requested additional information to complete its review of the reports (Accession No. ML16147A284). FENOC responded to this request by letter dated July 14, 2016 (Accession No. ML16196A318). In the response, FENOC identified changes needed to the original January 22, 2016 report. As a result, the report (Beaver Valley Unit 2 End-of-Cycle 18 Analysis and Prediction for End-of-Cycle 19 Voltage-Based Repair Criteria 90-Day Report, Revision 1) has been updated to reflect these changes. During the review of the revised report, FENOC identified additional changes, and as a result, the report was subsequently updated. Revision bars are included in the left margin to identify substantial or technical changes from the version previously submitted to the Document Control Desk. The need to revise the original January 22, 2016 report was documented in the FENOC Corrective Action Program. The current revision of the report is enclosed.

There are no regulatory commitments contained in this letter. If there are any questions or if additional information is required, please contact Mr. Thomas A. Lentz, Manager - Fleet Licensing, at 330-315-6810.

Sincerely,

Marty L. Richey

Enclosure: Beaver Valley Unit 2 End-of-Cycle 18 Analysis and Prediction for End-of-Cycle 19 Voltage-Based Repair Criteria 90-Day Report, Revision 5

cc: NRC Region I Administrator
NRC Resident Inspector
NRC Project Manager
Director BRP/DEP
Site BRP/DEP Representative

Enclosure
L-16-241
Beaver Valley Unit 2 End-of-Cycle 18 Analysis and Prediction for End-of-Cycle 19
Voltage-Based Repair Criteria 90-Day Report, Revision 5
(70 Pages to follow)

Westinghouse Non-Proprietary Class 3

SG-SGMP-15-22
Revision 5

September 2016

Beaver Valley Unit 2 End-of-Cycle 18 Analysis and Prediction for End-of-Cycle 19 Voltage-Based Repair Criteria 90-Day Report

Westinghouse

SG-SGMP-15-22
Revision 5

Beaver Valley Unit 2
End-of-Cycle 18 Analysis and Prediction for End-of-Cycle 19 Voltage-Based Repair Criteria 90 Day Report

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Steam Generator Management Programs

September 2016

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**Electronically approved records are authenticated in the Electronic Document Management System.*

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RECORD OF REVISIONS

Revision	Date	Description
0	December 2015	Original
1	January 2016	Editorial revisions to add commas and improve consistency. In Section 3.1, sentence added to better explain that specific inspection probes can only be used in Row 3 and 4 tubes with sleeves and indications on the cold leg side was corrected. Tables 3-1, 3-2, 3-3, and 6-1 and Figures 3-1, 3-2, 3-3, 6-1, 6-2, and 6-3 updated to show that no indications exist beyond 1.5V. Figures 3-5 and 3-6 updated to show that the Cycle 17 growth rate curve was use as it bounded the growth observed during Cycle 18. Note added to Table 7-2 to better explain the use of the Cycle 17 growth rate curve, and Maximum Volts for SG-B corrected. Comment column added to the tables in Appendix A. Change bars are used in the left margins where substantial or technical changes occurred. Change bars are not used for editorial changes such as formatting changes and minor non-technical corrections.
2	July 2016	Fixed Table 3-4, growth statistics no longer have new indications included. Fixed Table 3-5, added “per EFPY” as qualifier to voltage change. Adjusted Table 3-5 bin values and entries; entries were one row off. Fixed Table 6-1, OA inputs are corrected, resulting in new results. Fixed Table 7-2, results changed, see Table 6-1. Fixed Figures 6-2 and 6-3 to reflect results from corrected OA inputs. On page 3-3, added “none of these exceeded 0.5 volts” and “on a per EFPY basis.” Revised text on page 6-1, was 13 tubes and 13 indications, now 4 tubes and 6 indications. Maximum tube burst probability for the limiting SG was $3.61x10^{-5}$ at SG-B, now it is $4.87x10^{-5}$ at SG-B. Maximum leak rate was 0.303 gpm at SG-B, now it is 0.300 gpm at SG-B. This change was made on pages 1-1, 2-1, and 7-1. Change bars are used in the left margins where substantial or technical changes occurred.
3	July 2016	Fixed Table 3-2, corrected errors in the totals for the 0.7 and 1.0 voltage bins. Revision 3 of this document is a minor revision. Change bars for Revision 2 still exist in this document. Change bars are used in the left margins where substantial or technical changes occurred.
4	August 2016	Fixed Table 6-1 SG A entries. Simulation was re-run and table updated. Fixed Table 7-2. The number of indications at EOC-19 was 500, now it is 502. Leak rate was 0.191, it is now 0.195 gpm. Change bars are used in the left margins where substantial or technical changes occurred.

Revision	Date	Description
5	September 2016	Updated Table 6-1 entries for all SGs for consistency, using actual DSI voltage for bins above 1.1 volts instead of random sampling (SG-A and SG-C) in the largest bin. All SG rerun; SG A leak rate reduced to 0.189 gpm; SG C leak rate increased to 0.268 gpm, Table 7-2 updated to reflect these results. All other OA results remain consistent. Revised verbiage on pages 3-2 and 3-3 to clarify amplitudes greater than or equal to 1.0, but no greater than 1.5. Updated rev bars throughout document for consistency amongst earlier versions. Change bars are used in the left margins where substantial or technical changes occurred.

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1 INTRODUCTION

This report provides a summary of the Beaver Valley Unit 2 steam generator (SG) bobbin and **+Point™**[1] probe inspections at tube support plate (TSP) intersections from the Fall 2015, 2R18 outage, together with postulated Steam Line Break (SLB) leak rate and tube burst probability analyses. The 2R18 outage represents the third application of the Generic Letter (GL) 95-05 (Reference 1) voltage based repair criteria, and implementation of its requirements, to the Beaver Valley Unit 2 Model 51M SGs. The criteria were implemented during the 2R16 outage. Information required by the GL 95-05 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 18, representing a condition monitoring assessment of bobbin coil signal amplitudes for observed possible indications. In addition, a projection of EOC-19 bobbin coil voltage distributions, as well as the associated SG tube leak rates and burst probabilities through EOC-19 conditions is provided.

The condition monitoring analysis at End-of-Cycle 18 (EOC-18) was carried out using the actual bobbin coil voltage distributions measured during the 2R18 outage. These results show that the 2R18 condition monitoring leak rates and conditional burst probabilities for all three SGs are well within their respective allowable limits. A comparison with the projections made in the previous 90 Day Report at the 2R17 outage (Reference 2) shows that the predictions were very conservative. These evaluations utilized the Westinghouse generic methodology that uses Monte Carlo analysis techniques (Reference 3).

The operational assessment analysis was performed to project leak rates and tube burst probabilities for postulated SLB conditions at the end of the upcoming cycle (EOC-19) based on the 2.0 volt repair criteria for 7/8-inch diameter tubes. These analyses utilized bobbin voltage distributions measured during the recent (2R18) inspection and a growth rate distribution bounding the last two inspections (2R17 and 2R18). Leak and burst analyses for the operational assessment were performed using the Reference 4 default value primary-to-secondary pressure differential of 2560 psi. The Cycle 19 operational assessment predicts that SG B will be the limiting SG for projected leakage. With a Cycle 19 period of operation estimated at 550 effective full power days (EFPD), the limiting EOC-19 maximum leak rate for SG B is projected to be 0.300 gpm (room temperature), which is well below the allowable limit of 2.2 gpm for the faulted SG. The corresponding maximum tube burst probability for the limiting SG (SG B) of 4.87×10^{-5} is well below the GL 95-05 limit of 1.0×10^{-2}. Thus, the GL 95-05 requirements are predicted to be satisfied at the EOC-19.

[1] +Point™ is a trademark of Zetec, Inc.

2 SUMMARY AND CONCLUSIONS

A total of 1051 distorted support indications (DSI) in all three SGs combined were reported during the Beaver Valley Power Station Unit 2 (BVPS2) 2R18 bobbin coil inspection. Per GL 95-05, only those DSI signals with a bobbin coil signal amplitude of 2.0 volts or greater are required to be inspected using a +Point (or equivalent) probe. All DSI signals reported during 2R18 were less than 2.0 volts, so no indications were required to be tested with the +Point probe. However, some indications were tested with the +Point probe to confirm the minimal bobbin coil voltage growth condition. These indications were confirmed as axial outside diameter stress corrosion cracking (ODSCC) using the +Point probe during the 2R16 outage and have been inspected with a +Point probe at each successive outage. The maximum bobbin coil voltage indication in all three SGs was 1.46 volts on R21 C54 at the 02H tube support plate in SG-B.

SLB leak rate and tube burst probability analyses were performed using the actual 2R18 bobbin voltage distributions (condition monitoring analysis) as well as the projected EOC-19 bobbin voltage distributions (operational assessment). The SLB leak rates from the condition monitoring analysis show significant margins relative to the faulted SG allowable limit of 2.2 gpm (room temperature), Reference 11. The corresponding condition monitoring tube burst probability values are well below the allowable limit of 1.0×10^{-2}.

At 2R18, the largest SLB leak rate in the condition monitoring analysis is calculated for SG-B, with a magnitude of 0.0617 gpm, which is well below the allowable SLB leakage limit of 2.2 gpm in the faulted SG. All leak rate values quoted are equivalent volumetric rates at room temperature. The limiting conditional tube burst probability from the condition monitoring analysis, 1.57×10^{-5} also predicted for SG-B, is well below the Nuclear Regulatory Commission (NRC) reporting guideline of 1.0×10^{-2}. Thus, the condition monitoring results are well within the allowable limit/reporting guideline.

SLB leak rate and tube burst probability projections at the EOC-19 conditions were performed using the latest alternate repair criteria (ARC) database available for 7/8 inch outside diameter (OD) tubing (Addendum 7 update), which is documented in Reference 4. Leak and burst analyses for the Cycle 19 operational assessment were performed using the Reference 4 default primary-to-secondary pressure differential of 2560 psi. SG-B is predicted to be the limiting SG. For a projected Cycle 19 duration of 550 EFPD, the EOC-19 leak rate projected for SG-B using the GL 95-05 constant probability of detection (POD) of 0.6 is 0.300 gpm (at room temperature), which is less than the current limit of 2.2 gpm in the faulted SG. This leak rate projection utilized the leak rate calculation methodology of References 5 and 6. The limiting EOC-19 burst probability of 4.87×10^{-5} is calculated for SG-B and is well below the allowable limit of 1.0×10^{-2}. Therefore, all acceptance criteria of Reference 1 will be satisfied throughout Cycle 19.

3 2R18 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

3.1 2R18 Inspection Results

For outages prior to 2R16, the alternate repair criterion per GL 95-05 had been approved for BVPS2, but was not implemented. FirstEnergy Nuclear Operating Company (FENOC) had not implemented the criterion due to the small number of bobbin indications at TSP intersections which were confirmed to contain axial outside diameter stress corrosion cracking (ODSCC) using a +Point probe. The criterion was implemented at 2R16 due to an increase in the number of DSIs confirmed to contain axial ODSCC from +Point probe examination. It should be noted, for 2R16, and prior outages the bobbin probe analysis utilized the guidance and requirements of GL 95-05. Since the initial 2R16 (and prior outages) inspection plan did not assume that GL 95-05 would be implemented, all bobbin coil DSIs were inspected using a +Point probe. Note that under GL 95-05, only DSI signals with a 400/100 mix (hereafter referred to simply as the mix channel) signal amplitude of greater than 2.0 volts are required to be inspected using a +Point probe.

In accordance with the guidance provided by the NRC GL 95-05, the 2R18 inspection of the Beaver Valley Unit 2 SGs consisted of a 100% eddy current (EC) bobbin probe full length examination of the tube bundles in all three SGs. All hot and cold leg TSP intersections were inspected using 0.720 inch diameter bobbin probes, with the exception of those hot leg TSP intersections in Row 3 and Row 4 tubes, which contain SG tube sleeves at the hot leg top-of-tubesheet. In these tubes (2), a 0.630 inch diameter wide groove bobbin probe was used for DSI detection. If a DSI was observed using the 0.630 inch wide groove bobbin probe, an attempt was made to obtain an inspection of these locations using a 0.720 inch diameter bobbin probe from the cold leg side. If this probe could not pass over the U-bend, the tube was to be plugged as FENOC has not received NRC approval to utilize the reduced diameter probe results in the analysis. Prior evaluation of DSIs from other plants, which were inspected using both the 0.640 inch wide groove and 0.720 standard bobbin probe show that the voltage response from the 0.640 inch wide groove, is conservative compared to the voltage response of the 0.720 inch standard bobbin probe. A 0.630 diameter wide groove bobbin probe was used at 2R17 and 2R18. The performance characteristics of the 0.630 and 0.640 inch wide groove probe were reviewed and confirmed to be consistent. During the 2R17 outage, only one such indication was reported. During the 2R18 outage, none were reported. It should be noted that only two Row 3 or Row 4 tubes contain sleeves, both are Row 4 tubes.

To assess depth growth, the 2R17 DSIs with +Point probe confirmation were also inspected at 2R18, even though none were required to be inspected with a +Point probe due to the low bobbin amplitudes. This inspection showed little or no change in the +Point probe signal character was observed, thus implying little or no depth growth of the indication. The largest +Point probe signal amplitude in the 300 kHz channel from the confirmed DSI indications is only 0.2 volt, which represents a depth of 51% through-wall (TW) using the sizing protocol of Electric Power Research Institute (EPRI) Examination Technique Specification Sheet (ETSS I28431. Long term trending of the Unit 2 DSI population has shown a limited growth potential. For Cycles 10 through 18, the mean DSI voltage growth has been essentially zero.

Additionally, the +Point probe amplitudes for DSI signals confirmed as axial ODSCC have been much less than 1.0 volt, suggesting that a shallow depth of penetration exists. This in turn suggests the DSI voltage growth will remain minimal and not move to "extreme" over the next operating cycle. Thus, it can be concluded that, the character of DSI indications reported to date has been associated with a depth of penetration well below 100% TW.

In addition, the EOC-18 eddy current inspection plan included 100% +Point probe inspection of all hot leg and cold leg dents ≥5 volts (as measured from the bobbin probe), which exceeds the GL 95-05 requirement for testing of said dents of down to the lowest cold leg TSP with DSI reports. The 2R18 eddy current inspection plan also included 100% +Point probe inspection of dents with indication (DNI) and 25% of support plate residuals (SPR). The DNI call is generated using an auto data screening (ADS) process, and identifies any TSP intersection with a mix channel voltage of ≥1.25 volts with a phase angle of ≤55 degrees. This screening is performed for the detection of signals, which could be confirmed as axial primary water stress corrosion cracking (PWSCC) indications at TSP intersections. The identification of a DNI call is not solely restricted to the ADS output; the manual data analysis can also report DNI indications. A DNI call also does not imply that a possible indication is being reported at a dented TSP, only that the bobbin coil signal amplitude and phase angle are within the DNI reporting window. SPRs are defined as bobbin coil signals which do not contain flaw-like components but have a signal amplitude of ≥1.5 volts and phase angles >55 degrees. Axial ODSCC indications were not reported in these populations based on the +Point probe analysis. No axial PWSCC or circumferential stress corrosion cracking (SCC) was reported at any TSP intersection. The +Point probe inspection program for dents, DNIs, and SPRs was extensive. The following table provides the number of +Point probe exams performed at TSP intersections during 2R18.

SG	>5V Dents	DNI		SPR	
		Total	RPC Tested	Total	RPC Tested
A	16	427	427	993	353
B	37	79	79	260	83
C	16	222	222	153	66

The requirements of the GL 95-05 methodology in Section 1.b of Reference 1 are all satisfied. Tube intersections with the flow distribution baffle are excluded from this GL 95-05 analysis. There are no other excluded tube support plate intersections (Reference 7). None of the indications included in this analysis were detected in dents >5.0 volts, as measured by bobbin. All SPR indications >2V were tested with the +Point probe so that no ODSCC indications >1.0 volt would be missed or misread, as discussed earlier. No copper signal interference was detected.

Tables 3-1 through 3-3 present the 2R18 bobbin voltage data for the TSP intersections in the three SGs with distorted support indications (DSIs). A total of 1051 TSP locations had DSI indications in all three SGs combined, of which only 29 indications had amplitudes greater than or equal to 1.0 volt and no indications were greater than 1.5 volts. No DSI was above the

GL 95-05 lower voltage repair limit of 2.0 volts.

Tables 3-1 through 3-3 tabulate the number of field bobbin indications, the number of those indications that were +Point probe RPC inspected, the number of +Point probe RPC confirmed indications, and the number of indications 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. The distribution of 2R18 indications is also shown in Figures 3-1, 3-2 and 3-3 for SG-A, SG-B, and SG-C, respectively.

The distribution of 2R18 indications as a function of support plate location is summarized in Table 3-4 and shown in Figure 3-4. The data show a strong predisposition of ODSCC to occur in the first few hot leg TSPs although the mechanism extended to higher TSPs. Only eight indications were detected on the cold leg side; none of these exceeded 0.5 volt. This distribution is consistent with that observed at other plants and is commonly attributed to the temperature dependence of ODSCC.

Appendix A provides a listing of all DSIs reported at the BVPS 2R18 outage in the form of tables (Tables A-1, A-2, and A-3), whether axial ODSCC was confirmed (SAI/MAI in Comment column), and whether the tube contained the indication(s) was plugged (Comment column). No sleeves were installed at the 2R18 outage.

3.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at EOC-19, voltage growth rates were developed from the 2R17 and 2R18 inspection bobbin data. Growth is determined when the same indication can be identified in two successive inspections. Since there can be new indications in one outage, the number of indications for which a growth can be defined is less than the number of indications detected. Table 3-4 shows a distribution of growth as a function of TSP number. Table 3-5 shows the frequency and cumulative probability distribution of growth as a function of voltage change in each BVPS2 steam generator during Cycle 18 on a per EFPY basis.

The average bobbin coil voltage growth rates for each SG during Cycle 18 are given in Table 3-6. The average growth rates over the entire voltage range are negative indicating essentially no voltage growth. The Cycle 18 growth rates on an EFPY basis for each SG are shown in Figure 3-5. A magnification of the upper tail of this growth distribution is shown in Figure 3-6. Also shown in Figure 3-5 and in Figure 3-6 is a curve which bounds all of the growth curves for both Cycle 18 and Cycle 17 (Reference 2). The Cycle 17 bounding curve is more bounding than the Cycle 18 bounding curve therefore the Cycle 17 bounding curve is used in the operational assessment analysis to project the indication voltages at EOC-19.

Table 3-7 lists the top 15 indications based on Cycle 18 growth rate in descending order. The average growth rates over the entire voltage range for Cycle 18 are negative indicating essentially no voltage growth, but Table 3-7 shows that in cases of positive growth rates, that Cycle 18 had only modest growth. The growth during Cycle 18 for all indications was under 0.4 volts.

To determine if BVPS2 growth rates exhibited a potential dependency on the BOC voltage, the growth rate data for Cycle 18 was plotted against BOC voltage, and the resulting plot is shown in Figure 3-7. The Cycle 18 growth data do not show any tendency to increase with the BOC voltage; if at all, the growth seems to decrease with increasing 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) was applied during the 2R18 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 re-inspected with a good probe. As the repair limit for Beaver Valley Unit 2 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. Since no indications had amplitudes over 1.5 volts no tubes were retested due to the probe wear criteria being exceeded.

3.4 NDE Uncertainties

The NDE uncertainties applied for the Cycle 18 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those in the NRC Generic Letter 95-05 (Reference 1). The probe wear uncertainty has a standard deviation of 7.0% about a mean of zero and has a cut-off at 15% based on implementation of the probe wear standard. If the random sample of probe wear selected during the Monte Carlo simulations exceeds 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 cut-off. These nondestructive examination (NDE) uncertainty distributions are included in the Monte Carlo analyses for SLB leak rates and tube burst probabilities based on the 2R18 actual voltage distributions as well as for the EOC-19 projections.

Table 3-1 2R18 DSI Voltage Distribution for SG-A							
Voltage Bin	Number of Indications	+Point Probe Confirmed	+Point Probe Tested But Not Confirmed	Not +Point Probe Tested	Plugged	Returned to Service	In-Service, +Point Confirmed or +Point Not Tested
0.1	4	0	0	4	0	4	4
0.2	47	2	0	45	0	47	47
0.3	81	7	0	74	0	81	81
0.4	60	1	0	59	0	60	60
0.5	44	2	0	42	0	44	44
0.6	24	1	0	23	0	24	24
0.7	14	2	0	12	0	14	14
0.8	7	0	0	7	0	7	7
0.9	13	1	0	12	0	13	13
1	2	0	0	2	0	2	2
1.1	2	0	0	2	0	2	2
1.2	2	1	0	1	0	2	2
1.3	1	0	0	1	0	1	1
1.4	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
1.6	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0
1.8	0	0	0	0	0	0	0
1.9	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0
Total	301	17	0	284	0	301	301

Average voltage = 0.386 volts

Table 3-2 2R18 DSI Voltage Distribution for SG-B

Voltage Bin	Number of Indications	+Point Probe Confirmed	+Point Probe Tested But Not Confirmed	Not +Point Probe Tested	Plugged	Returned to Service	In-Service, +Point Confirmed or +Point Not Tested
0.1	6	1	0	5	0	6	6
0.2	62	3	0	59	1	61	61
0.3	109	6	0	103	1	108	108
0.4	66	4	0	62	0	66	66
0.5	63	3	0	60	1	62	62
0.6	46	2	0	44	0	46	46
0.7	31	5	0	26	1	30	30
0.8	12	2	0	10	0	12	12
0.9	10	0	0	10	0	10	10
1	5	0	0	5	0	5	5
1.1	5	0	0	5	0	5	5
1.2	2	0	0	2	0	2	2
1.3	0	0	0	0	0	0	0
1.4	0	0	0	0	0	0	0
1.5	1	0	0	1	0	1	1
1.6	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0
1.8	0	0	0	0	0	0	0
1.9	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0
Total	418	26	0	392	4	414	414

Average voltage = 0.401 volts

Table 3-3 2R18 DSI Voltage Distribution for SG-C

Voltage Bin	Number of Indications	+Point Probe Confirmed	+Point Probe Tested But Not Confirmed	Not +Point Probe Tested	Plugged	Returned to Service	In-Service, +Point Confirmed or +Point Not Tested
0.1	3	0	0	3	0	3	3
0.2	50	2	0	48	0	50	50
0.3	71	2	0	69	0	71	71
0.4	59	2	0	57	0	59	59
0.5	44	2	0	42	1	43	43
0.6	35	4	0	31	0	35	35
0.7	30	3	0	27	1	29	29
0.8	17	2	0	15	0	17	17
0.9	14	1	0	13	0	14	14
1	2	1	0	1	0	2	2
1.1	3	0	0	3	0	3	3
1.2	0	0	0	0	0	0	0
1.3	4	0	0	4	0	4	4
1.4	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
1.6	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0
1.8	0	0	0	0	0	0	0
1.9	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0
Total	332	19	0	313	2	330	330

Average voltage = 0.424 volts

Table 3-4 Indication Distribution as Function of Tube Support Plate

SG-A						SG-B					
TSP	Number of Indications	Max. Volts	Ave. Volts	Largest Growth, Volts	Average Growth, Volts	TSP	Number of Indications	Max. Volts	Ave. Volts	Largest Growth, Volts	Average Growth, Volts
02H	110	1.23	0.40	0.39	-0.04	02H	178	1.46	0.43	0.35	-0.03
03H	85	1.03	0.42	0.3	-0.03	03H	128	1.15	0.43	0.28	-0.02
04H	40	0.7	0.35	0.2	-0.03	04H	50	1.01	0.36	0.26	-0.04
05H	41	0.83	0.36	0.32	-0.04	05H	34	0.77	0.31	0.14	0.00
06H	8	0.44	0.28	0.17	-0.02	06H	8	0.42	0.29	0.09	-0.04
07H	5	0.66	0.41	0.14	0.00	07H	8	0.41	0.28	0.08	-0.04
08H	9	0.41	0.26	0.08	-0.01	08H	7	0.73	0.29	0.00	-0.13
04C	0	-	-	-	-	04C	1	0.14	0.14	0.02	0.02
06C	2	0.3	0.25	0.08	0.03	06C	2	0.15	0.14	0.00	-0.08
08C	1	0.28	0.28	0.02	0.02	08C	2	0.33	0.29	0.00	-0.01
Total	301					Total	418				
SG-C						**Composite**					
TSP	Number of Indications	Max. Volts	Ave. Volts	Largest Growth, Volts	Average Growth, Volts	TSP	Number of Indications	Max. Volts	Ave. Volts	Largest Growth, Volts	Average Growth, Volts
02H	135	1.3	0.51	0.36	-0.04	02H	423	1.46	0.45	0.39	-0.04
03H	99	1.04	0.41	0.36	-0.06	03H	312	1.15	0.42	0.36	-0.03
04H	41	0.71	0.31	0.19	-0.02	04H	131	1.01	0.34	0.26	-0.03
05H	29	0.77	0.37	0.11	-0.04	05H	104	0.83	0.34	0.32	-0.03
06H	13	0.35	0.22	0.06	-0.10	06H	29	0.44	0.26	0.17	-0.05
07H	7	0.51	0.26	-0.05	-0.13	07H	20	0.66	0.31	0.14	-0.05
08H	8	1.08	0.42	0.04	-0.07	08H	24	1.08	0.32	0.08	-0.07
04C	0	-	-	-	-	04C	1	0.14	0.14	0.02	0.02
06C	0	-	-	-	-	06C	4	0.3	0.19	0.08	-0.03
08C	0	-	-	-	-	08C	3	0.33	0.29	0.02	0.01
Total	332					Total	1051				

Table 3-5 Voltage Growth Cumulative Distribution

	SG-A		SG-B		SG-C		Composite	
Voltage Change: EOC-18 minus EOC-17 per EFPY	**Number of Indications**	**Cumulative Probability Distribution**	**Number of Indications**	**Cumulative Probability Distribution**	**Number of Indications**	**Cumulative Probability Distribution**	**Number of Indications**	**Cumulative Probability Distribution**
-0.8<ΔV≤-0.7	0	0.0000	0	0.0000	0	0.0000	0	0.0000
-0.7<ΔV≤-0.6	0	0.0000	0	0.0000	0	0.0000	0	0.0000
-0.6<ΔV≤-0.5	0	0.0000	0	0.0000	0	0.0000	0	0.0000
-0.5<ΔV≤-0.4	0	0.0000	0	0.0000	0	0.0000	0	0.0000
-0.4<ΔV≤-0.3	0	0.0000	0	0.0000	0	0.0000	0	0.0000
-0.3<ΔV≤-0.2	18	0.0612	13	0.0327	17	0.0520	48	0.0471
-0.2<ΔV≤-0.1	33	0.1735	41	0.1357	43	0.1835	117	0.1619
-0.1 <ΔV≤-0.0	130	0.6156	198	0.6332	173	0.7125	501	0.6536
0.0<ΔV≤0.1	87	0.9116	127	0.9523	81	0.9602	295	0.9431
0.1<ΔV≤0.2	22	0.9864	16	0.9925	10	0.9908	48	0.9902
0.2<ΔV≤0.3	4	1.0000	3	1.0000	3	1.0000	10	1.0000
0.3<ΔV≤0.4	0	1.0000	0	1.0000	0	1.0000	0	1.0000
0.4<ΔV≤0.5	0	1.0000	0	1.0000	0	1.0000	0	1.0000
0.5<ΔV≤0.6	0	1.0000	0	1.0000	0	1.0000	0	1.0000
0.6<ΔV≤0.7	0	1.0000	0	1.0000	0	1.0000	0	1.0000
0.7<ΔV≤0.8	0	1.0000	0	1.0000	0	1.0000	0	1.0000
Number of Indications with Growth	294		398		327		1019	

Table 3-6 Growth Rate as Function of BOC Voltage Range

Voltage Range		Number of Indications for Growth	Average BOC Voltage	Average Voltage Growth per Cycle 18	Average Voltage Growth per EFPY
Composite					
Entire Range		1019	0.442	-0.0360	-0.0271
Vboc<0.75		914	0.389	-0.0312	-0.0234
Vboc≥0.75		105	0.903	-0.0782	-0.0587
SG-A					
Entire Range		294	0.416	-0.0314	-0.0236
Vboc<0.75		268	0.369	-0.0259	-0.0194
Vboc≥0.75		26	0.897	-0.0881	-0.0662
SG-B					
Entire Range		398	0.433	-0.0280	-0.0211
Vboc<0.75		362	0.385	-0.0253	-0.0190
Vboc≥0.75		36	0.907	-0.0556	-0.0417
SG-C					
Entire Range		327	0.477	-0.0500	-0.0375
Vboc<0.75		284	0.412	-0.0437	-0.0329
Vboc≥0.75		43	0.902	-0.0912	-0.0685

Table 3-7 Indications with the Largest Growth in Cycle 18

SG	Row	Col	TSP #	EOC-18 Volts	EOC-17 Volts	C18 Growth, Volts	+Point Probe Tested
A	5	26	02H	1.01	0.62	0.39	No
C	22	20	02H	1.3	0.94	0.36	No
C	7	40	03H	0.73	0.37	0.36	No
B	9	52	02H	0.86	0.51	0.35	No
A	13	39	05H	0.7	0.38	0.32	No
A	5	10	03H	0.74	0.44	0.30	No
A	7	18	03H	0.88	0.59	0.29	No
B	5	52	02H	0.89	0.6	0.29	No
B	13	77	03H	1.05	0.77	0.28	No
C	12	9	02H	0.64	0.37	0.27	No
B	30	50	04H	1.01	0.75	0.26	No
A	16	70	03H	0.47	0.22	0.25	No
A	5	29	02H	1.13	0.89	0.24	Yes
B	9	85	02H	0.86	0.63	0.23	No
B	30	55	03H	0.63	0.40	0.23	No

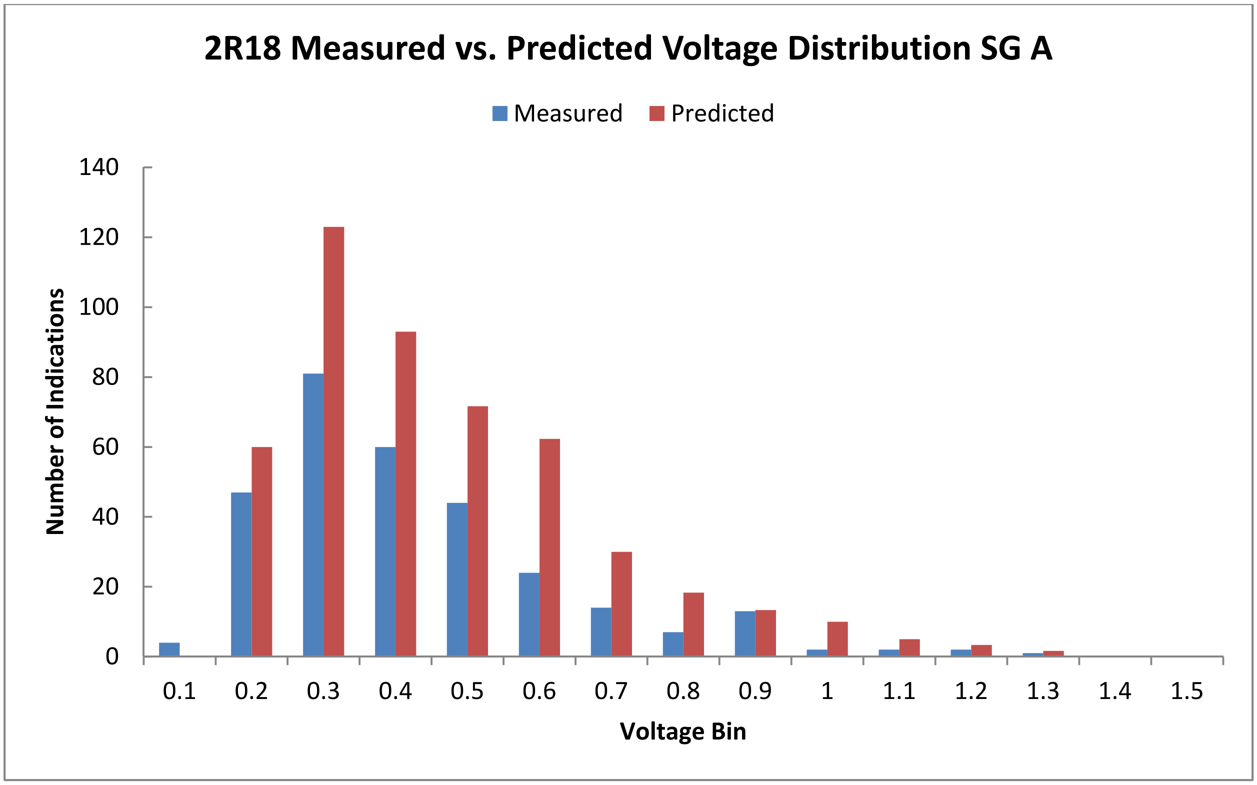

Figure 3-1 Measured Bobbin DSI Voltage, 2R18 SG-A

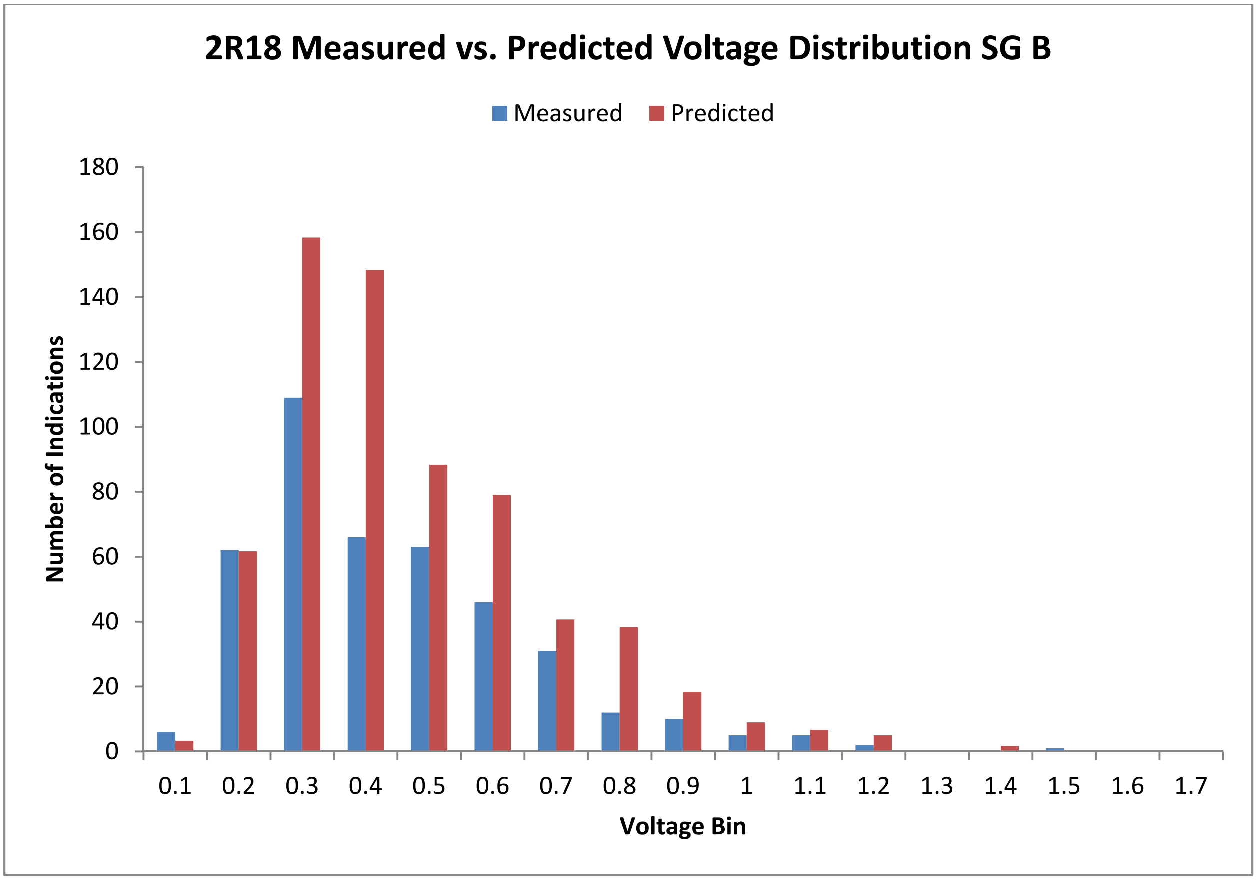

Figure 3-2 Measured Bobbin DSI Voltage, 2R18 SG-B

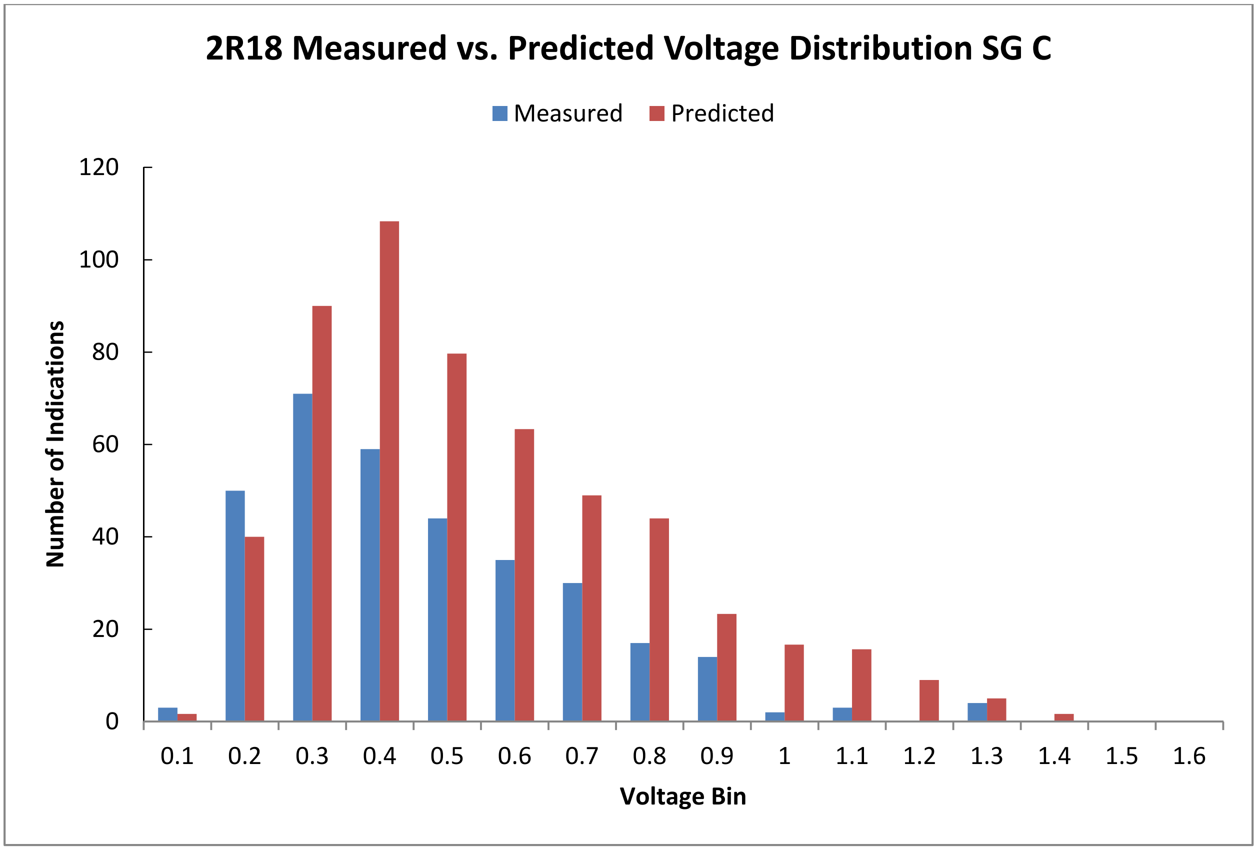

Figure 3-3 Measured Bobbin DSI Voltage, 2R18 SG-C

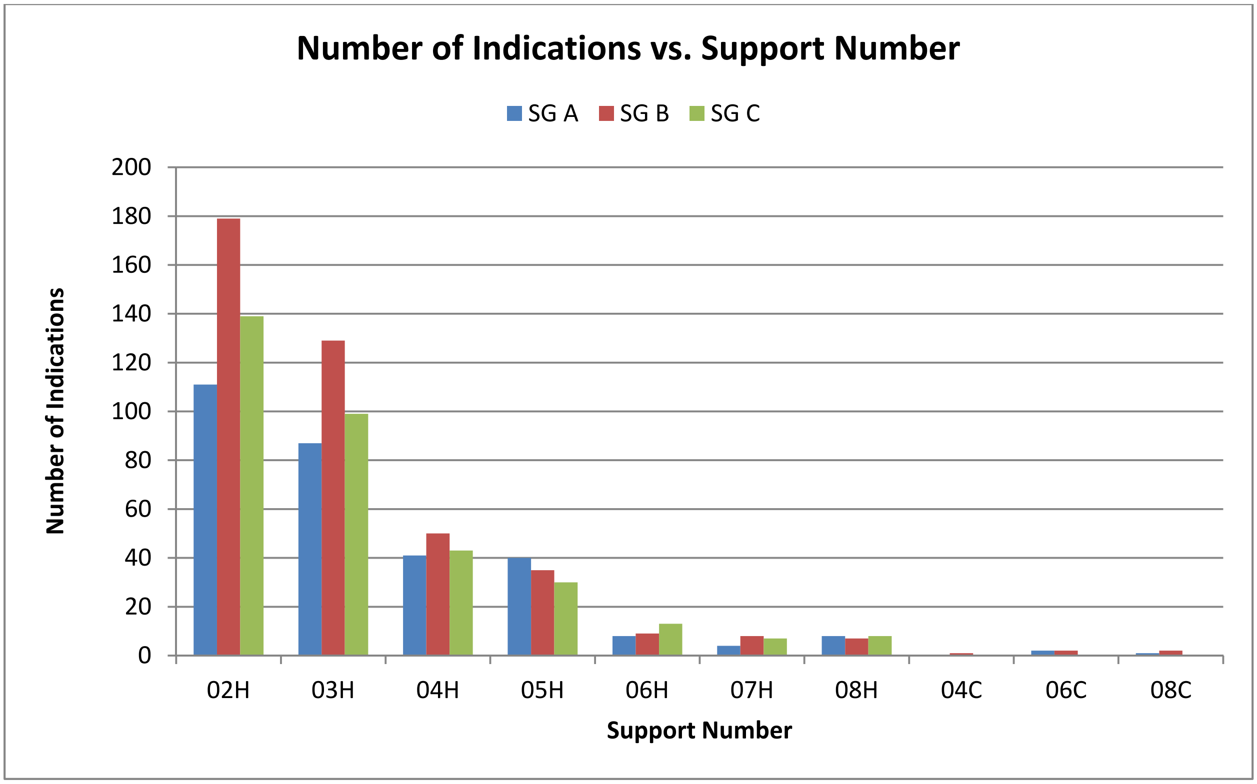

Figure 3-4 Number of Measured Bobbin DSI as a Function of TSP

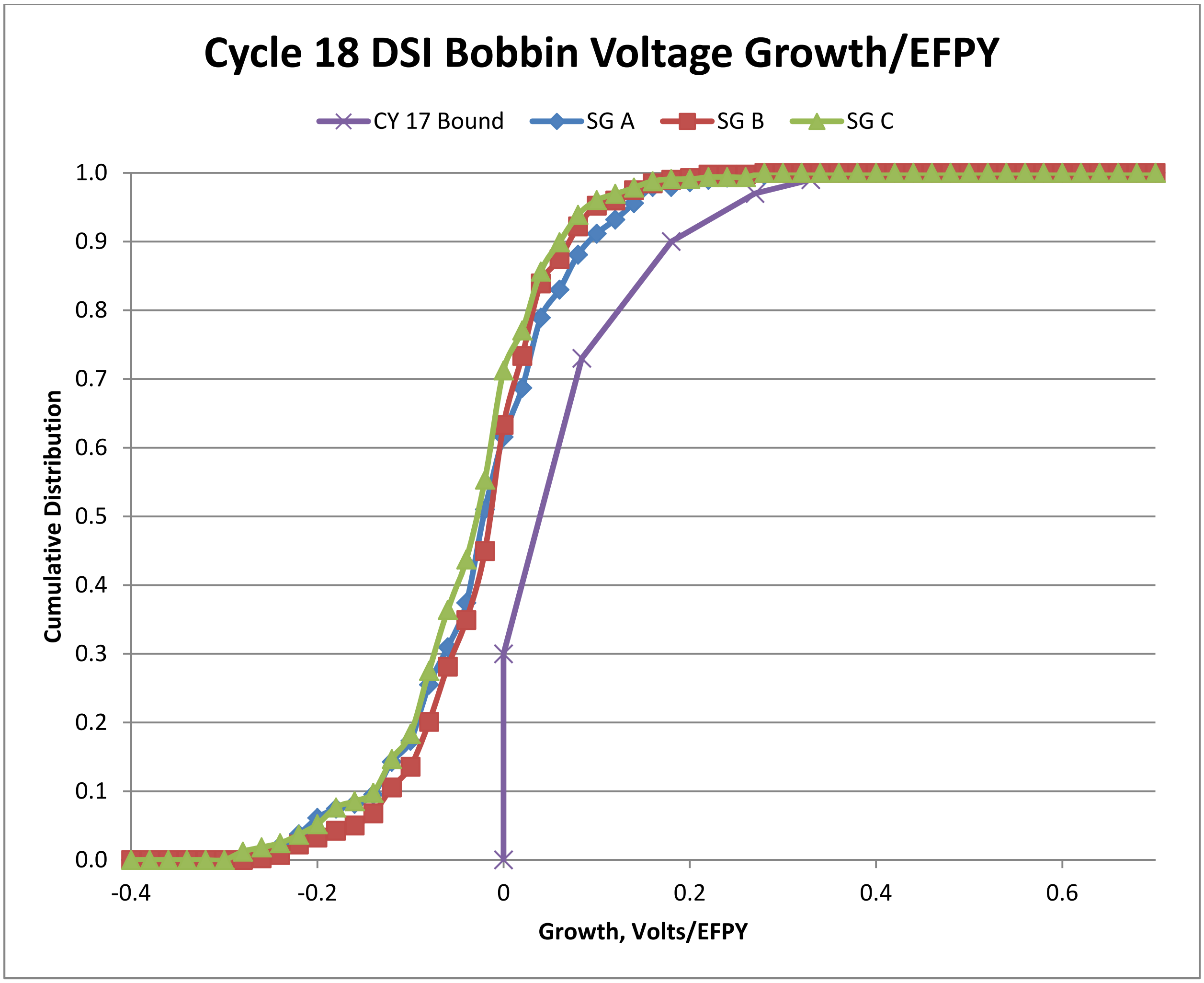

Figure 3-5 Voltage Growth during Cycle 18

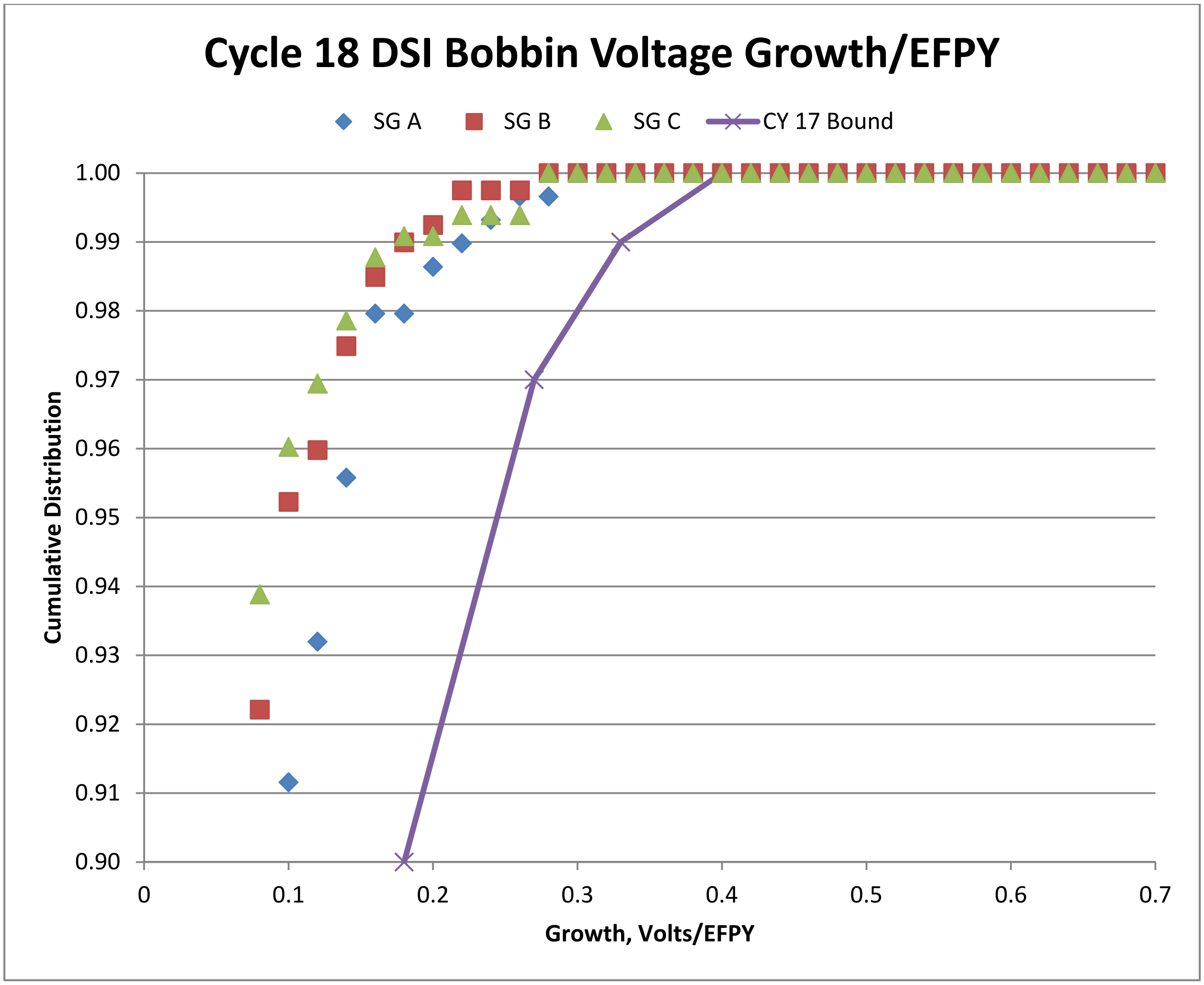

Figure 3-6 Expansion of Figure 3-5 at Extreme Voltage Growth during Cycle 18

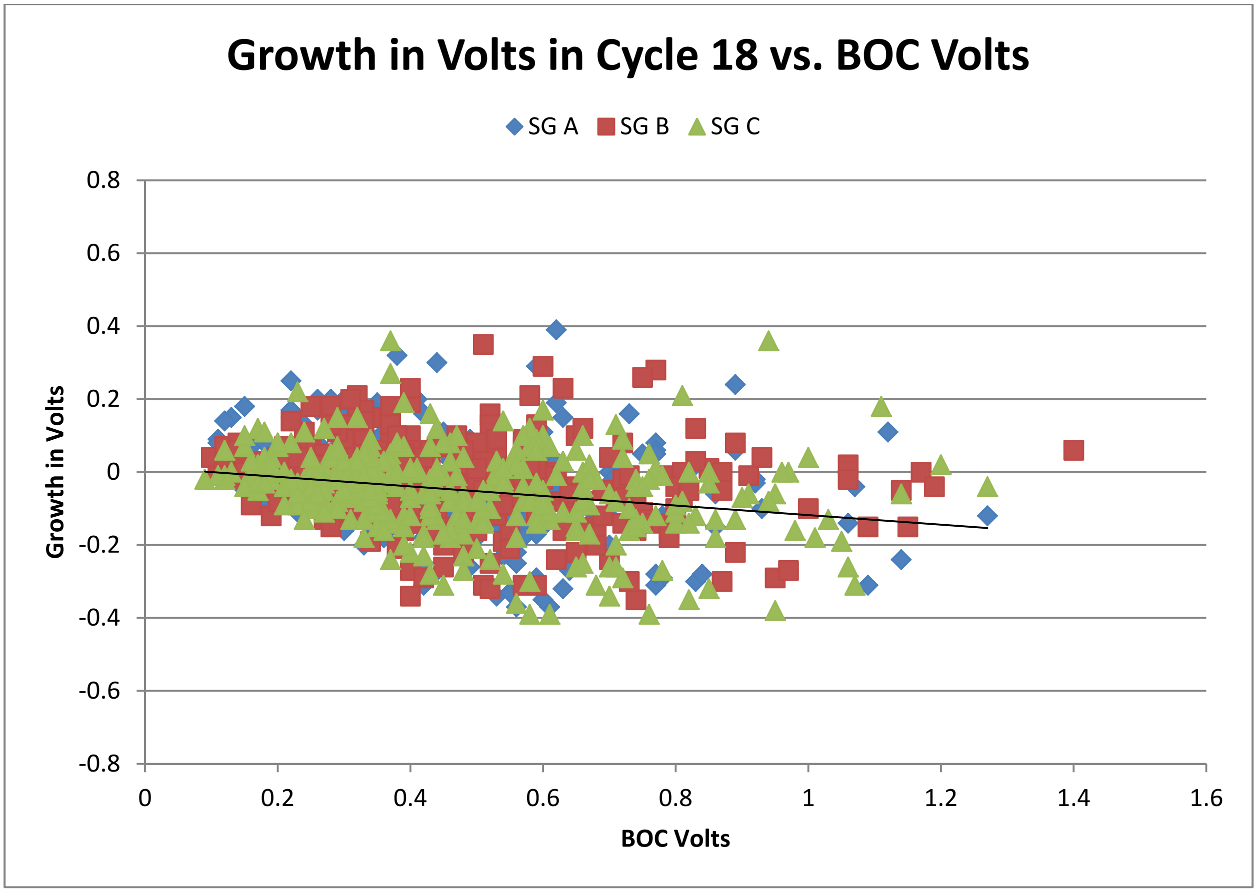

Figure 3-7 Voltage Growth in Cycle 18 vs. BOC Voltage

4 DATABASE APPLIED FOR LEAK AND BURST CORRELATIONS

4.1 Tube Material Properties

The tube material properties are provided in Table 4-1 of Reference 4 for 7/8-inch diameter tubes at 650°F. The parameters used in the analysis are the flow stress mean (sum of yield and ultimate strengths divided by 2) of 68.78 ksi and the flow stress standard deviation of 3.1725 ksi.

4.2 Burst Correlation

The burst pressure, P_b, is normalized to a material with a flow stress of 68.78 ksi, which is the mean of the Westinghouse 7/8-inch tube data. The actual material property values for Beaver Valley Unit 2 are slightly higher than the average of all Westinghouse data. The correlation parameters shown in Table 4-1 are taken from Reference 4.

4.3 Leak Rate Correlation

The steam line break pressure to be applied is 2560 psi unless a lower pressure can be justified. Therefore, the leak correlation for pressure of 2560 psi from Reference 4 is used for the leakage predictions. The parameters are shown in Table 4-2. The leak rate criterion is given in terms of gallons per minute as condensed liquid at room temperature.

4.4 Probability of Leak Correlation

The probability of leak as a function of indication voltage is taken from Reference 4. The parameters are shown in Table 4-3. In the Monte Carlo analysis leakage is quantified only if the indication is computed to be a leaker, based on the probability of leak correlation.

4.5 NDE Uncertainties

The NDE uncertainties applied for the EOC-18 and EOC-19 voltage projections are described in Reference 1. The probe wear uncertainty has a standard deviation of 7% about a mean of zero and has a cut-off at 15% based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cut-off. These NDE uncertainty distributions are used in the Monte Carlo analysis to predict the burst probabilities and accident leak rates at EOC-18 and EOC-19. The voltages reported were adjusted to account for differences between the laboratory standard and the standard used in the field.

4.6 Upper Voltage Repair Limit

Per Table 5.4-20 of Reference 12, the BVPS-2 Updated Final Safety Analysis Report (UFSAR), the pressurizer safety relief valves have a nominal setting of 2485 psig, or the Reactor Coolant System (RCS) design pressure. Applying a 3% allowance for accumulation per Section 2 of Attachment 1 to GL 95-05, the applicable SLB conditions pressure differential across the SG tubes is then 2560 psig, which is the traditional pressure differential used for prior GL 95-05

analyses. The upper voltage repair limit of 4.55 volts is based on the structural limit in Table 4-1 for a pressure differential of 2560 psi with a safety factor of 1.4 applied to the differential pressure. The upper voltage repair limit considers the projected voltage growth during the next cycle and NDE uncertainty. The maximum average percentage growth rate as a percentage of BOC voltage values for any steam generator is seen from Table 3-6 to be very small. According to Reference 1, the minimum growth adjustment is 30% per EFPY (45.2% per cycle for the bounding 550 EFPD Cycle 19). Therefore the specific maximum growth value of 45.2% and 20% for NDE uncertainty was used to estimate the upper voltage repair limit. This results in an upper voltage repair limit of 7.51 / (1 + 0.452 + 0.20) = 4.55 volts. No indications greater than this voltage were left in service; the largest DSI voltage reported at 2R18 was 1.46 volts.

The analysis takes no credit for power operated relief valve (PORV) actuation even though the PORVs, block valves, and associated testing programs have been shown to satisfy the requirements of GL 90-06, as indicated in the NRC Safety Evaluation Report dated May 15, 1995. Crediting the PORVs would effectively increase the upper voltage repair limit by limiting the maximum pressure differential during a postulated SLB event and would reduce the calculated SLB conditions by limiting the maximum pressure differential.

Considering the inspection history of the BVPS2 SGs, it is unlikely that a bobbin coil DSI voltage of >4.5 volts will be observed within the BVPS2 SGs.

Table 4-1 7/8" Tube Burst Pressure vs. Bobbin Amplitude Correlation Parameters

$$P_B = a_0 + a_1 \log(Volts\ )$$

Parameter	Addendum 7 Database Value
Intercept, a_0	7.4801
Slope, a_1	-2.4002
Index of Deter., r^2	79.67%
Std. Deviation, σ_{Error}	0.8802
Mean of Log(*V*)	0.3111
SS of Log(*V*)	51.6595
N (data pairs)	100
Str. Limit (2560 psi) (1)	7.51V
Str. Limit (2405 psi)	9.40V
p Value for a_1 (2)	$5.60 \cdot 10^{-36}$
Reference σ_f	68.78 ksi (3)

Notes: (1) Values reported correspond to applying a safety factor of 1.4 on the differential pressure associated with a postulated SLB event.

(2) Numerical values are reported only to demonstrate compliance with the requirement that the value be less than 0.05.

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

Table 4-2 Tube Leak Rate vs. Bobbin Amplitude Correlation Parameters

$$Q = 10^{[b_3 + b_4 \log(Volts)]}$$

Parameter	Addendum 7 Database Value
SLB ΔP = 2560 psi	
Intercept, b_3	-0.33476
Slope, b_4	0.95311
Index of Determination, r^2	12.4%
Residuals, σ_{Error} (b_5)	0.8175
Mean of Log(Q)	0.7014
SS of Log(Q)	22.8754
p Value for b_4	2.4%
SLB ΔP = 2405 psi	
Intercept, b_3	-0.8039
Slope, b_4	1.2077
Index of Determination, r^2	20.0%
Residuals, σ_{Error} (b_5)	0.7774
Mean of Log(Q)	0.5090
SS of Log(Q)	22.6667
p Value for b_4	0.5%
Common Data	
Data Pairs, N	32
Mean of Log(V)	1.0871
SS of Log(V)	3.1116

Table 4-3 7/8" Tube Probability of Leak Correlation Parameters

$$\Pr(Leak) = \frac{1}{1 + e^{-\left[b_1 + b_2 \log(Volts)\right]}}$$

Parameter	Addendum 7 Database Value
Logistic Intercept, b_1	-4.9847
Logistic Slope, b_2	7.6110
Intercept Variance, V_{11} (1)	1.2904
Covariance, V_{12}	-1.7499
Slope Variance, V_{22}	2.8181
Number of Data, N	120
Deviance	33.66
Pearson SD	62.9%
MSE	0.285

Note: (1) Parameters V_{ij} are the elements of the covariance matrix of the coefficients, $\beta_{i,}$ of the regression equation.

5 SLB ANALYSIS METHODS

A Monte Carlo analysis technique is used to calculate the SLB leak rates and tube burst probabilities for both actual 2R18 and projected EOC-19 voltage distributions. The Monte Carlo analysis accounts for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 4 as supplemented by References 5 and 6. The Monte Carlo computer program used to implement this method is documented in Reference 9. Essentially the same methodology was applied to leak and burst analyses performed for the original Beaver Valley Unit 1 SGs, Reference 10.

In general, the methodology involves application of correlations for burst pressure, probability of leakage and leak rate to a measured or calculated EOC voltage 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 probability of detection (POD) used to generate the BOC voltage distributions considers both detection uncertainty and the likely occurrence of new indications. 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.

6 BOBBIN VOLTAGE DISTRIBUTIONS

This section describes the input data used to calculate EOC bobbin voltage distributions and presents results of calculations to project EOC-19 voltage distributions.

6.1 Calculation of Voltage Distributions

The analysis for EOC-19 voltage distribution starts with an initial voltage distribution which is projected to the end-of-cycle conditions based on the growth rate and the anticipated cycle operating duration. 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 using a POD, which accounts for both the detection uncertainty and the development 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 by inspection 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 the beginning of Cycle 19 (BOC-19); therefore, $N_{deplugged} = 0$. Four tubes with 6 indications at the TSPs were plugged, therefore $N_{repaired} = 6$. These tubes were plugged for reasons other than the presence of the DSI signal. 2R18 RPC "no degradation found" (NDF) indications were included in establishing the BOC-19 indication distributions shown in Table 6-1. During the Monte Carlo simulations, voltages for bins with several indications are selected by randomly sampling the voltage bins. For a few higher voltage indications in each SG, 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-19 bobbin voltage frequency distributions is described in Reference 3, and it is essentially the same as that used in the original Beaver Valley Unit 1 SGs, Reference 10.

6.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 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. In this report the Reference 1 POD value 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. For conservatism, a growth rate curve which bounded the growth rates of both cycles was used. 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 18 - 493 EFPD or 1.331 EFPY (actual)

Cycle 19 - 550 EFPD or 1.506 EFPY (projected)

6.5 Projected EOC-19 Voltage Distribution

Calculations for the EOC-19 bobbin voltage projections were performed for all three SGs based on the 2R18 distributions shown in Table 6-1. The BOC-19 distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-19 is also shown in Table 6-1. Calculations were performed using a constant POD of 0.6 and 1,000,000 Monte Carlo trials. The distribution of indications at BOC-19 and the distribution of indications projected to EOC-19 are shown in Figures 6-1, 6-2, and 6-3 for SG-A, SG-B, and SG-C, respectively. SG-B has the largest number of indications at BOC-19. Reporting the maximum predicted voltage is not required by GL 95-05, but it is arbitrarily chosen to be the voltage where the integration of the upper tail of the voltage distribution reaches a 0.3 fractional indication.

Table 6-1 Predicted Voltage Distribution at EOC-19

	SG-A Number of Indications				SG-B Number of Indications				SG-C Number of Indications		
Volt Bins	**Measured**	**Input**	**Predicted**		**Measured**	**Input**	**Predicted**		**Measured**	**Input**	**Predicted**
	EOC-18	**BOC-19**	**EOC-19**		**EOC-18**	**BOC-19**	**EOC-19**		**EOC-18**	**BOC-19**	**EOC-19**
0.1	4	6.67	3.04		6	10	4.34		3	5	2.64
0.2	47	78.33	26.22		62	102.33	34.79		50	83.33	26.46
0.3	81	135	63.46		109	180.67	83.21		71	118.33	60.95
0.4	60	100	85.29		66	110	109.05		59	98.33	79.92
0.5	44	73.33	84.40		63	104	107.93		44	72.33	82.46
0.6	24	40	72.56		46	76.67	100.3		35	58.33	76.07
0.7	14	23.33	54.52		31	50.67	81.96		30	49	64.87
0.8	7	11.67	38.40		12	20	60.34		17	28.33	51.79
0.9	13	21.67	26.43		10	16.67	41.02		14	23.33	38.16
1	2	3.33	17.83		5	8.33	26.74		2	3.33	26.02
1.1	2	3.33	11.59		5	8.33	17.1		3	5	16.56
1.2	2	3.33	7.36		2	3.33	10.65		0	0	10.14
1.3	1	1.67	4.62		0	0	6.43		4	6.68	6.20
1.4			2.79		0	0	3.77				3.81
1.5			1.58		1	1.67	2.19				2.33
1.6			0.58				1.26				1.38
1.7			0				0.6				0.58
1.8			0.7				0				0
1.9			0.3				0.7				0.7
2							0.3				0.3
Total	301	502	502		418	693	693		332	551	551

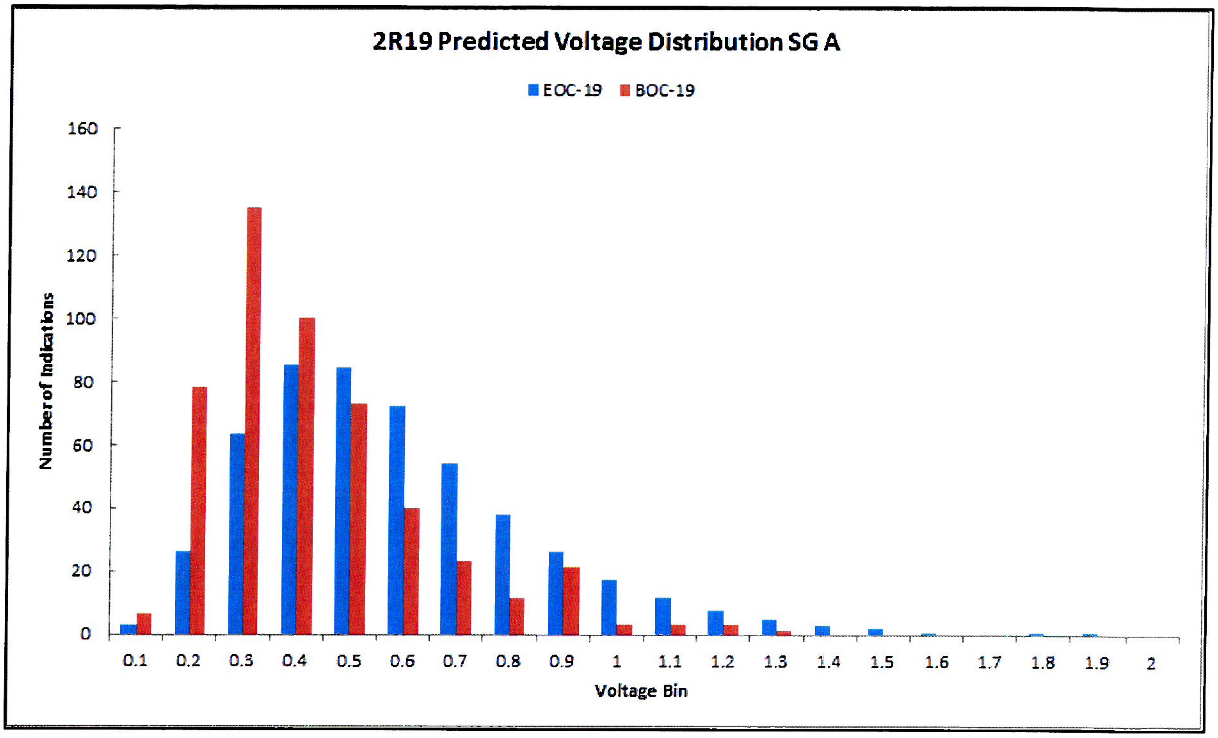

Figure 6-1 Predicted Voltage Distribution at EOC-19, SG-A

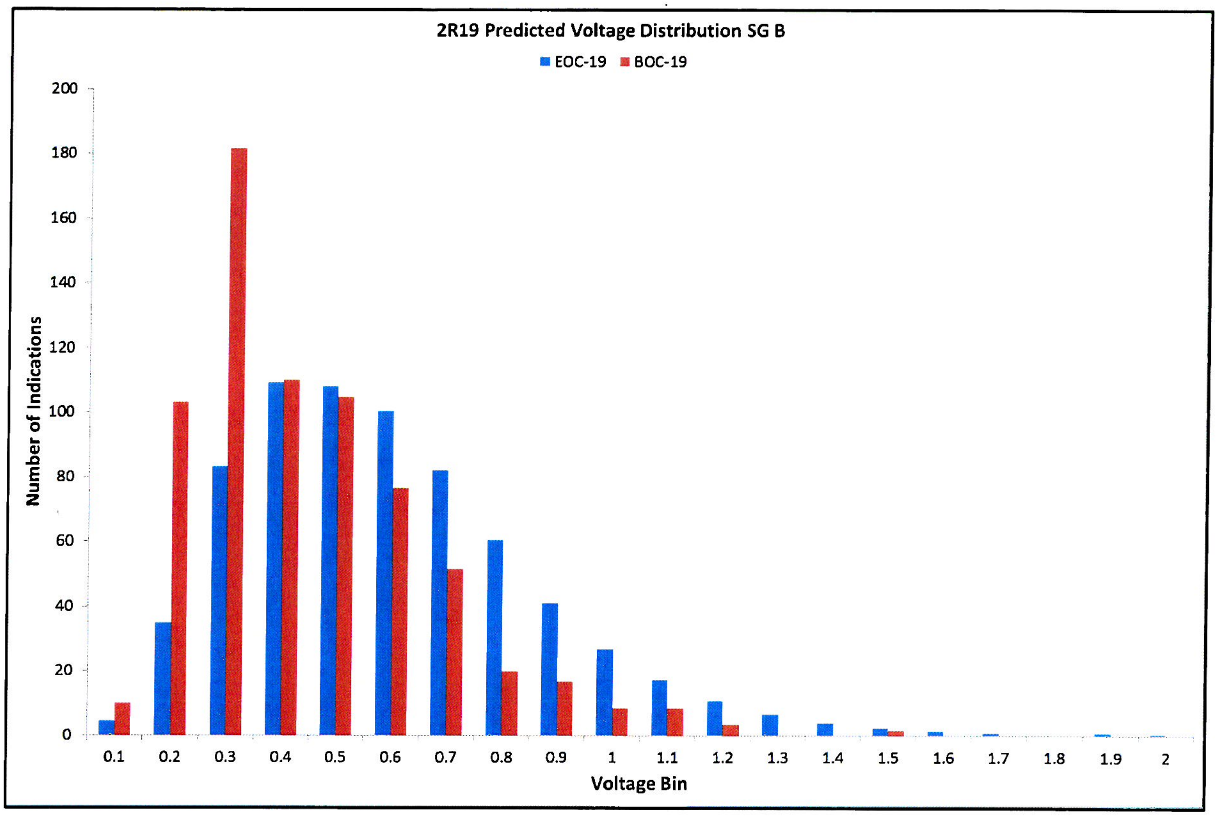

Figure 6-2 Predicted Voltage Distribution at EOC-19, SG-B

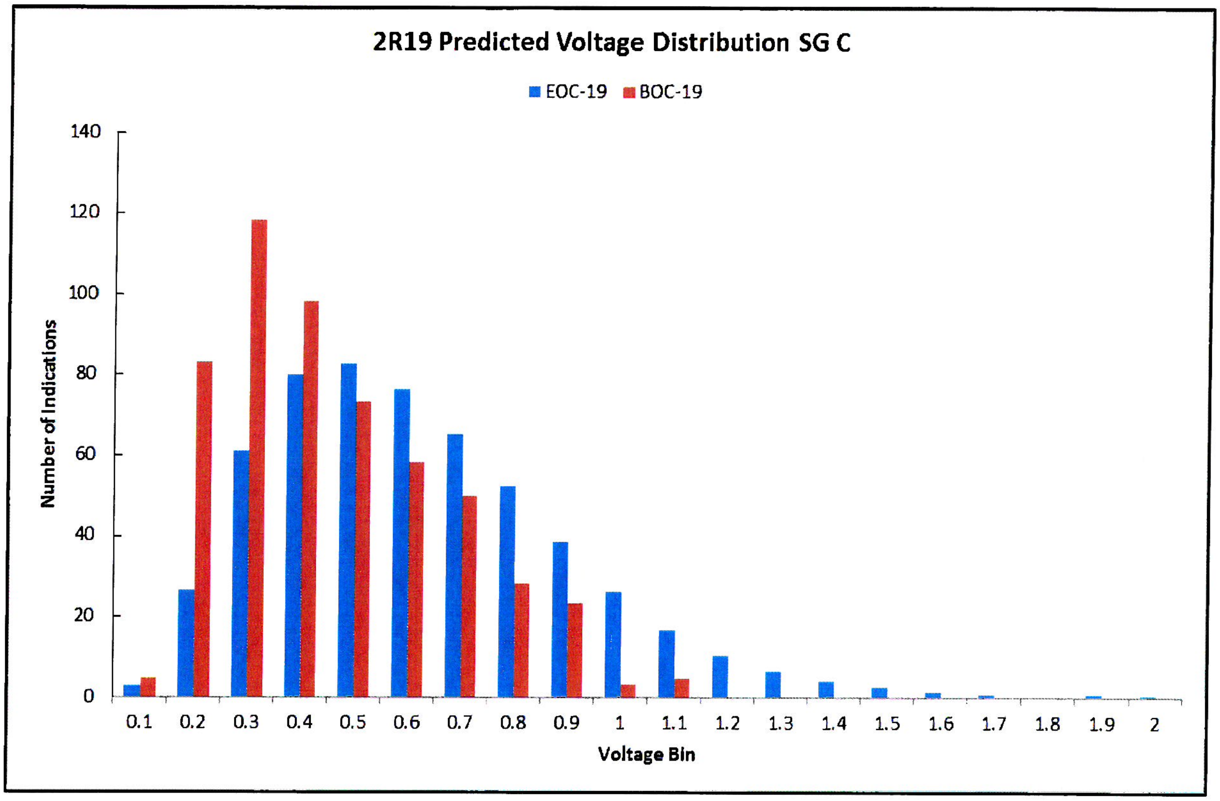

Figure 6-3 Predicted Voltage Distribution at EOC-19, SG-C

7 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 2R18 inspection (condition monitoring assessment) as well as for the projected EOC-19 voltage distributions (operational assessment). The methodology used in these analyses is described in Section 6.

7.1 2R18 Condition Monitoring Leak Rate and Tube Burst Probability

Analyses to calculate the 2R18 SLB leak rates and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Tables 3-1 to 3-3. The results of the Monte Carlo calculations are summarized in Table 7-1.

The SLB leak rates and tube burst probabilities, calculated using the actual measured 2R18 voltage distributions using 1,000,000 Monte Carlo trials, are shown in Table 7-1. The methodology used for these calculations is documented in WCAP-14277, Rev. 1. The probability of leak, leak rate and burst pressure correlations for 7/8 inch tubes presented in the latest addendum to the EPRI Alternate Repair Criteria (ARC) Database, Reference 3, were used. The SLB primary-to-secondary pressure differential applied in the analysis is 2560 psi. The maximum 2R18 leak rate of 0.0617 gpm and the maximum conditional burst probability of 1.57×10^{-5} are well below their respective allowable limits (2.2 gpm per Reference 11, and 1.0×10^{-2} per Reference 1, respectively). Therefore, the condition monitoring performance criteria are satisfied.

7.2 Cycle 19 Operational Assessment Leak Rate and Tube Burst Probability

The SLB leak rate and tube burst probability projection for the Cycle 19 operational assessment was carried out using the latest update to the ARC database documented in Reference 4, the POD of 0.60, and 1,000,000 Monte Carlo trials. The EOC-19 leak and burst analyses were performed using a primary-to-secondary pressure differential of 2560 psi, even though it is likely that PORV actuation will occur prior to the pressurizer safety relief valve lift setting.

The EOC-19 projections, considering a 550 EFPD operation cycle, using POD = 0.6 are shown in Table 7-2. Both the maximum projected EOC-19 leak rate of 0.300 gpm and the maximum conditional burst probability of 4.87×10^{-5} are well below their respective allowable limits (2.2 gpm and 1.0×10^{-2}, respectively). Therefore, the operational assessment performance criteria for the DSI indications are satisfied for Cycle 19.

Table 7-1 Condition Monitoring Leak and Burst Results for 2R18				
	Number of Indications at EOC-18	**Maximum Volts at EOC-18**	**Probability of 1 or More Burst at 95% Confidence**	**SLB Leak Rate at 95/95 (gpm)**
SG-A	301	1.23	1.05×10^{-5}	0.0394
SG-B	418	1.46	1.57×10^{-5}	0.0617
SG-C	332	1.3	7.75×10^{-6}	0.0485

Table 7-2 Operational Assessment Leak and Burst Results for EOC-19 (POD = 0.6)					
	Growth Rate Used in Projection	**Number of Indications at EOC-19**	**Maximum Volts at EOC-19**	**Probability of 1 or More Burst**	**SLB Leak Rate at 95/95 (gpm)**
SG-A	Cycle 17 Bound	502	1.9	2.67×10^{-5}	0.189
SG-B	Cycle 17 Bound	693	2.0	4.87×10^{-5}	0.300
SG-C	Cycle 17 Bound	551	2.0	3.14×10^{-5}	0.268

Note: The growth rate for Cycle 17 bounds the growth rate observed during Cycle 18.

8 REFERENCES

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

2. Westinghouse Report, SG-SGMP-14-17, Rev. 1, “Beaver Valley Unit 2 End-of-Cycle 17 Analysis and Prediction for End-of-Cycle 18 Voltage-Based Repair Criteria 90-Day Report,” July 2014.

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APPENDIX A

Table A-1: DSI Indications for 2R18 in SG-A

SG	Row	Col	Locn	2R18 Volts	Comment
2A	2	24	07H	0.52	SAI
2A	2	88	02H	0.29	
2A	2	92	03H	0.33	
2A	3	15	03H	0.8	
2A	3	59	02H	0.58	
2A	3	65	07H	0.66	
2A	3	77	08H	0.41	SAI
2A	3	79	07H	0.39	
2A	3	81	03H	0.83	
2A	3	84	03H	0.59	
2A	3	85	04H	0.7	
2A	3	92	02H	0.27	
2A	4	9	03H	0.71	
2A	4	9	04H	0.48	
2A	4	18	05H	0.19	
2A	4	21	03H	0.65	
2A	4	24	02H	0.41	
2A	4	26	02H	0.37	
2A	4	34	03H	0.25	
2A	4	39	02H	0.25	
2A	4	50	02H	0.36	
2A	4	50	03H	0.83	
2A	4	50	04H	0.49	
2A	4	54	02H	0.58	
2A	4	54	04H	0.46	
2A	4	54	05H	0.46	
2A	4	60	02H	0.2	
2A	4	60	06H	0.34	
2A	4	63	02H	0.55	
2A	4	78	05H	0.27	
2A	4	85	08C	0.28	
2A	5	10	02H	1.15	
2A	5	10	03H	0.74	
2A	5	10	04H	0.51	
2A	5	11	04H	0.37	
2A	5	25	05H	0.71	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	5	26	02H	1.01	
2A	5	26	03H	0.89	
2A	5	29	02H	1.13	SAI
2A	5	30	03H	0.43	
2A	5	53	02H	0.23	
2A	5	80	05H	0.26	
2A	5	82	03H	0.44	
2A	6	15	02H	0.39	
2A	6	27	06H	0.2	
2A	6	32	02H	0.2	
2A	6	34	02H	0.28	
2A	6	35	02H	0.78	
2A	6	35	03H	0.49	
2A	6	35	05H	0.44	
2A	6	35	08H	0.29	
2A	6	40	03H	0.33	
2A	6	40	04H	0.26	
2A	6	41	08H	0.21	SAI
2A	6	43	02H	0.65	
2A	7	14	03H	0.34	
2A	7	18	03H	0.88	
2A	7	18	05H	0.37	
2A	7	19	03H	0.46	
2A	7	27	05H	0.34	
2A	7	49	02H	0.18	
2A	7	51	02H	0.27	
2A	7	58	03H	0.43	
2A	7	71	03H	0.23	
2A	7	94	02H	0.25	
2A	8	19	02H	0.36	
2A	8	28	02H	0.33	
2A	8	29	02H	0.26	
2A	8	32	03H	0.32	
2A	8	32	05H	0.83	SAI
2A	8	34	03H	1.03	
2A	8	42	02H	0.28	
2A	8	69	02H	0.17	
2A	8	76	05H	0.19	
2A	8	85	02H	0.1	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	8	91	04H	0.51	
2A	9	10	02H	0.85	
2A	9	13	02H	0.53	
2A	9	14	03H	0.2	
2A	9	16	02H	0.54	
2A	9	16	03H	0.66	
2A	9	16	04H	0.56	
2A	9	34	02H	0.23	SAI
2A	9	35	02H	0.31	
2A	9	38	05H	0.83	
2A	9	40	03H	0.36	
2A	9	51	04H	0.61	SAI
2A	9	56	02H	0.24	
2A	9	56	04H	0.5	
2A	9	57	02H	0.18	
2A	9	57	03H	0.65	
2A	9	74	03H	0.15	
2A	10	7	02H	0.85	
2A	10	7	03H	0.29	
2A	10	8	03H	0.3	
2A	10	19	04H	0.36	
2A	10	26	04H	0.2	
2A	10	37	03H	0.13	
2A	11	2	03H	0.56	
2A	11	48	02H	0.9	
2A	11	48	08H	0.4	
2A	11	77	05H	0.51	
2A	11	78	06H	0.39	
2A	12	34	02H	0.25	
2A	12	48	05H	0.31	
2A	12	69	03H	0.39	
2A	12	70	03H	0.47	
2A	12	72	02H	0.25	
2A	12	73	05H	0.17	
2A	12	74	02H	0.41	
2A	12	74	03H	0.58	
2A	13	32	02H	0.33	
2A	13	39	05H	0.7	
2A	13	49	04H	0.14	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	13	60	02H	0.46	
2A	13	67	06C	0.3	
2A	13	71	04H	0.41	
2A	13	80	03H	0.24	
2A	13	84	02H	0.53	
2A	13	85	02H	0.61	
2A	13	86	03H	0.4	
2A	13	91	05H	0.51	
2A	13	92	04H	0.45	
2A	14	15	04H	0.22	
2A	14	20	03H	0.27	
2A	14	25	05H	0.31	
2A	14	27	05H	0.28	
2A	14	31	02H	0.17	
2A	14	40	05H	0.28	SAI
2A	14	48	05H	0.34	
2A	14	50	03H	0.25	
2A	14	53	02H	0.17	
2A	14	54	02H	0.48	
2A	14	58	02H	0.32	
2A	14	59	02H	0.14	
2A	14	59	03H	0.24	
2A	14	59	06H	0.44	
2A	14	65	03H	0.38	
2A	14	68	02H	0.34	
2A	14	70	03H	0.78	
2A	14	80	03H	0.21	
2A	14	86	04H	0.5	
2A	15	27	05H	0.21	
2A	15	63	02H	0.4	
2A	15	67	02H	0.31	
2A	15	71	02H	0.2	
2A	15	72	02H	0.38	
2A	15	73	03H	0.7	
2A	15	73	05H	0.31	
2A	15	74	03H	0.95	
2A	15	75	02H	0.47	
2A	15	75	08H	0.27	SAI
2A	16	11	05H	0.15	SAI

SG	Row	Col	Locn	2R18 Volts	Comment
2A	16	52	02H	0.49	
2A	16	53	03H	0.35	
2A	16	62	08H	0.12	
2A	16	66	03H	0.42	
2A	16	70	03H	0.47	
2A	16	72	02H	0.19	
2A	16	76	02H	0.37	
2A	16	77	05H	0.13	
2A	17	10	03H	0.23	
2A	17	27	04H	0.25	
2A	17	32	05H	0.51	
2A	17	46	02H	0.81	
2A	17	59	02H	0.27	
2A	17	59	05H	0.14	
2A	17	81	03H	0.27	
2A	17	81	04H	0.24	
2A	17	84	03H	0.26	
2A	18	7	04H	0.17	
2A	18	10	03H	0.6	
2A	18	10	04H	0.19	
2A	18	27	07H	0.21	
2A	18	47	02H	0.24	
2A	18	47	05H	0.4	
2A	18	57	02H	0.67	
2A	18	88	05H	0.14	
2A	19	7	02H	0.56	
2A	19	7	03H	0.31	SAI
2A	19	8	03H	0.37	
2A	19	15	03H	0.27	
2A	19	15	04H	0.22	
2A	19	56	03H	0.25	
2A	19	57	02H	0.65	
2A	19	57	04H	0.23	
2A	19	60	02H	0.11	
2A	20	9	03H	0.22	
2A	20	10	04H	0.31	
2A	20	12	02H	0.29	
2A	20	22	02H	0.32	
2A	20	22	03H	0.4	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	20	22	08H	0.27	
2A	20	57	02H	0.11	
2A	20	62	05H	0.49	
2A	20	75	05H	0.2	
2A	20	78	04H	0.16	
2A	20	85	03H	0.16	
2A	21	18	04H	0.39	
2A	21	25	03H	0.18	
2A	21	26	05H	0.42	
2A	21	34	02H	0.3	
2A	21	43	02H	0.1	
2A	21	46	02H	0.22	
2A	21	55	02H	0.14	
2A	21	72	03H	0.48	
2A	21	73	03H	0.8	
2A	21	78	08H	0.1	
2A	22	7	02H	0.38	
2A	22	21	02H	0.19	
2A	22	21	03H	0.19	
2A	22	23	02H	0.19	
2A	22	25	02H	0.26	
2A	23	11	02H	0.9	
2A	23	11	03H	0.24	
2A	23	19	02H	0.89	
2A	23	20	02H	0.23	
2A	23	21	03H	0.17	
2A	23	53	02H	0.45	SAI
2A	23	87	04H	0.34	
2A	24	16	02H	0.27	
2A	24	16	03H	0.11	
2A	24	23	05H	0.65	SAI
2A	24	24	02H	0.27	
2A	24	33	03H	0.26	
2A	24	52	02H	0.21	
2A	24	63	05H	0.34	
2A	25	21	02H	0.12	
2A	25	22	02H	0.46	
2A	25	30	04H	0.46	
2A	26	15	03H	0.17	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	26	19	04H	0.28	
2A	26	42	02H	0.34	
2A	26	80	05H	0.22	
2A	27	32	02H	0.34	
2A	27	33	03H	0.57	
2A	27	34	04H	0.25	
2A	27	42	04H	0.23	SAI
2A	27	42	05H	0.22	
2A	27	47	02H	0.45	
2A	27	64	02H	0.19	
2A	27	75	05H	0.28	
2A	28	13	03H	0.3	
2A	28	26	04H	0.34	
2A	28	41	02H	0.33	
2A	28	45	02H	0.42	
2A	28	46	03H	0.36	
2A	28	54	02H	0.22	
2A	28	56	03H	0.5	
2A	28	66	04H	0.1	SAI
2A	29	24	04H	0.39	
2A	29	54	03H	0.29	MAI
2A	29	65	02H	0.33	
2A	30	19	02H	0.31	
2A	30	22	02H	0.45	
2A	30	28	03H	0.26	
2A	30	38	02H	0.12	
2A	30	58	04H	0.31	
2A	30	63	08H	0.23	
2A	30	68	02H	0.36	
2A	31	14	04H	0.25	
2A	31	18	02H	0.92	
2A	31	18	03H	0.42	
2A	32	22	02H	0.36	
2A	32	27	03H	0.3	
2A	32	38	03H	0.26	
2A	32	45	02H	0.54	
2A	32	51	05H	0.25	
2A	32	53	03H	0.39	
2A	33	18	02H	0.19	

SG	Row	Col	Locn	2R18 Volts	Comment
2A	33	18	03H	0.34	
2A	33	42	05H	0.23	
2A	33	45	07H	0.25	
2A	33	54	06H	0.23	
2A	33	57	04H	0.44	
2A	33	66	02H	0.55	
2A	34	52	02H	0.28	
2A	34	53	02H	0.42	
2A	34	56	05H	0.54	
2A	35	45	02H	0.53	
2A	36	28	03H	0.48	
2A	36	28	04H	0.14	
2A	36	44	03H	0.32	
2A	36	46	06H	0.21	
2A	37	39	03H	0.37	
2A	37	42	03H	0.42	
2A	37	54	05H	0.2	
2A	37	56	02H	0.3	
2A	37	56	03H	0.61	
2A	38	40	05H	0.35	
2A	38	44	02H	0.42	
2A	39	23	02H	1.23	
2A	39	42	02H	0.58	
2A	39	46	02H	0.49	
2A	39	57	03H	0.24	
2A	40	37	03H	0.82	
2A	40	44	06C	0.19	
2A	42	64	04H	0.5	
2A	44	35	03H	0.5	
2A	44	58	06H	0.13	
2A	46	52	06H	0.29	

Table A-2: DSI Indications for 2R18 in SG-B

SG	Row	Col	Locn	2R18 Volts	Comment
2B	1	43	02H	0.47	
2B	1	52	02H	0.19	
2B	1	56	02H	0.28	
2B	1	57	04H	0.72	
2B	2	24	02H	0.43	
2B	2	28	02H	0.61	
2B	2	54	04H	0.24	
2B	2	62	03H	0.58	
2B	2	63	04H	0.32	
2B	2	67	06H	0.26	
2B	2	70	05H	0.77	
2B	2	73	03H	0.43	
2B	2	73	04H	0.38	
2B	2	94	04H	0.46	
2B	3	32	03H	0.29	
2B	3	54	02H	0.38	
2B	3	55	02H	0.63	
2B	3	60	02H	0.58	
2B	3	60	03H	0.57	
2B	3	61	06H	0.27	
2B	3	62	03H	0.41	
2B	3	62	04H	0.29	
2B	3	63	02H	0.66	
2B	3	63	03H	0.53	
2B	3	72	03H	0.58	
2B	3	88	04H	0.6	
2B	3	89	04H	0.45	
2B	4	23	02H	0.32	
2B	4	23	06H	0.28	
2B	4	32	03H	0.13	
2B	4	36	04H	0.1	SAI
2B	4	41	04H	0.25	
2B	4	43	02H	0.2	
2B	4	44	02H	0.41	
2B	4	48	03H	0.46	
2B	4	52	03H	0.58	
2B	4	54	02H	0.53	
2B	4	56	04H	0.22	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	4	57	02H	0.38	
2B	4	57	04H	0.2	
2B	4	58	02H	0.35	
2B	4	59	02H	0.49	
2B	4	59	03H	0.25	
2B	4	63	04H	0.57	
2B	5	10	02H	0.62	
2B	5	12	03H	0.23	
2B	5	14	03H	0.58	
2B	5	20	03H	0.35	
2B	5	22	04H	0.47	
2B	5	28	02H	0.62	
2B	5	52	02H	0.89	
2B	5	54	02H	0.28	
2B	5	54	03H	0.23	
2B	5	56	03H	0.53	
2B	5	58	02H	0.21	
2B	5	60	02H	0.31	
2B	5	63	04H	0.16	
2B	5	64	02H	0.43	
2B	5	64	03H	0.39	
2B	5	68	02H	0.49	
2B	5	71	02H	0.5	
2B	5	73	02H	0.43	
2B	5	75	04H	0.17	
2B	5	81	05H	0.24	
2B	5	92	02H	0.5	
2B	5	93	03H	0.33	
2B	6	16	03H	0.26	
2B	6	23	04H	0.25	
2B	6	26	02H	0.25	
2B	6	27	03H	0.29	SAI
2B	6	52	02H	0.12	
2B	6	53	02H	0.35	
2B	6	53	03H	0.06	
2B	6	58	02H	0.56	
2B	6	61	08H	0.16	
2B	6	63	02H	0.2	
2B	6	66	03H	1.15	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	6	70	05H	0.56	
2B	7	52	02H	0.7	
2B	7	54	02H	0.07	
2B	7	56	02H	0.58	
2B	7	56	06C	0.15	
2B	7	63	07H	0.34	
2B	7	70	04H	0.72	
2B	7	70	05H	0.3	
2B	7	75	02H	0.14	
2B	8	2	03H	0.2	
2B	8	9	02H	0.44	
2B	8	9	03H	0.28	
2B	8	18	02H	0.49	
2B	8	18	03H	0.51	
2B	8	20	02H	0.25	
2B	8	22	02H	0.17	
2B	8	37	03H	0.41	
2B	8	53	02H	0.7	
2B	8	56	03H	0.38	
2B	8	57	08H	0.2	
2B	8	59	02H	0.41	
2B	9	4	03H	0.34	SAI
2B	9	5	03H	0.27	
2B	9	8	03H	0.22	
2B	9	11	02H	0.58	
2B	9	11	03H	0.39	
2B	9	16	03H	0.19	
2B	9	17	02H	0.53	
2B	9	17	03H	0.36	
2B	9	18	02H	0.34	
2B	9	18	03H	0.5	
2B	9	26	02H	0.46	
2B	9	26	03H	0.78	
2B	9	52	02H	0.86	
2B	9	52	03H	0.33	
2B	9	59	03H	0.59	
2B	9	59	05H	0.28	
2B	9	64	04H	0.74	SAI
2B	9	72	04H	0.65	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	9	80	02H	0.53	
2B	9	85	02H	0.86	
2B	9	92	02H	0.43	
2B	9	93	02H	0.29	
2B	10	6	02H	0.58	
2B	10	10	02H	0.17	
2B	10	14	02H	0.43	
2B	10	15	02H	0.36	
2B	10	17	02H	0.39	
2B	10	18	02H	0.57	
2B	10	26	02H	0.59	
2B	10	37	03H	0.21	
2B	10	41	07H	0.35	
2B	10	50	02H	0.3	
2B	10	50	03H	0.35	
2B	10	52	02H	1.17	
2B	10	52	04H	0.38	
2B	10	53	02H	0.35	
2B	10	54	02H	0.46	
2B	10	56	02H	0.25	
2B	10	58	05H	0.29	
2B	10	63	02H	0.44	
2B	10	71	05H	0.38	
2B	10	78	04H	0.26	
2B	10	80	03H	0.24	
2B	10	82	03H	0.31	
2B	10	88	04C	0.14	
2B	10	89	02H	0.38	
2B	11	8	03H	0.24	
2B	11	8	04H	0.14	
2B	11	9	06H	0.15	
2B	11	9	07H	0.28	
2B	11	18	02H	0.58	
2B	11	20	02H	0.52	
2B	11	21	03H	0.3	
2B	11	25	03H	0.44	SAI
2B	11	35	02H	0.14	
2B	11	42	03H	0.19	
2B	11	53	02H	0.37	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	11	53	08C	0.33	
2B	11	57	03H	0.24	
2B	11	58	03H	0.4	
2B	11	58	04H	0.23	
2B	11	61	02H	1	
2B	11	61	03H	0.68	
2B	11	64	03H	0.48	
2B	11	75	02H	0.86	
2B	11	75	03H	0.44	
2B	11	83	03H	0.26	
2B	11	83	04H	0.43	
2B	12	10	02H	0.56	
2B	12	15	02H	0.29	
2B	12	15	03H	0.59	
2B	12	16	03H	0.13	
2B	12	22	02H	0.47	
2B	12	24	02H	0.38	
2B	12	24	04H	0.25	
2B	12	51	02H	0.13	
2B	12	52	02H	0.26	
2B	12	52	03H	0.65	
2B	12	61	03H	0.97	
2B	13	16	02H	0.68	plug
2B	13	16	03H	0.18	plug
2B	13	16	06H	0.41	plug
2B	13	37	03H	0.34	
2B	13	39	07H	0.13	
2B	13	47	02H	0.24	SAI
2B	13	53	02H	0.68	
2B	13	56	03H	0.31	
2B	13	73	02H	0.39	
2B	13	77	03H	1.05	
2B	13	78	02H	0.1	
2B	13	85	02H	0.26	
2B	13	86	02H	0.16	
2B	13	91	02H	0.34	
2B	14	8	03H	0.2	
2B	14	13	02H	0.48	
2B	14	15	03H	0.5	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	14	18	02H	0.48	
2B	14	25	02H	0.51	
2B	14	27	03H	0.27	
2B	14	28	05H	0.22	
2B	14	32	02H	0.31	
2B	14	35	06H	0.26	
2B	14	36	03H	0.25	
2B	14	39	02H	0.07	
2B	14	54	02H	0.64	
2B	14	54	03H	0.56	
2B	14	57	02H	0.48	
2B	14	57	03H	0.52	
2B	14	61	02H	0.21	
2B	14	61	03H	0.63	
2B	14	61	05H	0.48	
2B	14	63	03H	0.65	
2B	14	70	02H	0.53	
2B	14	84	04H	0.36	
2B	14	88	02H	0.23	
2B	15	12	03H	0.14	
2B	15	26	03H	0.39	
2B	15	26	07H	0.27	
2B	15	27	02H	0.27	
2B	15	36	02H	0.24	
2B	15	51	02H	0.24	SAI, plug
2B	15	52	02H	0.61	
2B	15	71	05H	0.47	
2B	15	75	02H	0.22	
2B	15	75	04H	0.27	
2B	15	80	04H	0.4	
2B	15	87	02H	0.23	
2B	15	89	02H	0.34	
2B	16	27	03H	0.48	
2B	16	29	02H	0.17	SAI
2B	16	31	02H	0.3	
2B	16	31	07H	0.19	
2B	16	37	02H	0.35	
2B	16	37	04H	0.2	SAI
2B	16	44	02H	0.46	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	16	55	05H	0.32	
2B	16	61	02H	0.38	
2B	16	71	02H	0.17	
2B	17	35	03H	0.53	
2B	17	42	03H	0.62	
2B	17	42	04H	0.46	
2B	17	44	02H	0.29	SAI
2B	17	64	02H	0.13	
2B	17	68	02H	0.66	
2B	17	68	03H	0.39	
2B	17	68	04H	0.76	SAI
2B	17	83	06C	0.12	
2B	18	12	03H	0.25	
2B	18	18	02H	0.17	
2B	18	28	04H	0.41	
2B	18	29	02H	0.81	
2B	18	30	04H	0.23	
2B	18	36	03H	0.94	
2B	18	37	03H	0.53	
2B	18	38	03H	0.61	
2B	18	42	02H	0.3	
2B	18	53	03H	0.5	
2B	18	53	04H	0.2	
2B	18	54	02H	0.95	
2B	18	57	03H	0.12	
2B	18	58	02H	0.54	
2B	18	61	03H	0.4	
2B	18	64	03H	0.44	
2B	18	69	05H	0.47	
2B	18	76	03H	0.36	
2B	19	15	02H	0.25	
2B	19	15	04H	0.19	
2B	19	29	02H	0.9	
2B	19	29	03H	0.97	
2B	19	36	02H	0.9	
2B	19	39	03H	0.67	
2B	19	39	04H	0.47	
2B	19	40	03H	0.45	
2B	19	45	02H	0.37	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	19	50	03H	0.64	
2B	19	51	02H	0.68	
2B	19	51	03H	0.58	
2B	19	69	02H	0.77	
2B	19	71	05H	0.57	
2B	19	74	02H	0.13	
2B	19	76	02H	0.51	
2B	19	78	02H	0.26	
2B	19	85	02H	0.14	
2B	20	11	02H	1.09	
2B	20	16	03H	0.43	
2B	20	19	04H	0.1	
2B	20	23	02H	0.17	SAI
2B	20	70	02H	0.14	
2B	20	81	02H	0.27	
2B	20	89	02H	0.5	
2B	21	45	04H	0.34	
2B	21	53	03H	0.46	
2B	21	53	05H	0.22	
2B	21	54	02H	1.46	
2B	21	75	02H	0.18	
2B	22	12	03H	0.13	
2B	22	18	03H	0.7	SAI
2B	22	36	03H	0.24	
2B	22	52	02H	0.22	
2B	22	52	03H	0.27	
2B	22	53	02H	0.15	
2B	22	61	05H	0.21	
2B	22	62	03H	0.48	
2B	22	64	02H	0.52	
2B	23	33	03H	0.39	
2B	23	37	04H	0.68	SAI
2B	23	56	02H	0.26	
2B	23	61	02H	0.3	
2B	23	63	03H	0.29	
2B	23	63	05H	0.2	
2B	23	67	05H	0.22	
2B	23	86	02H	0.22	
2B	24	29	05H	0.29	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	24	30	03H	0.31	
2B	24	32	03H	0.29	
2B	24	42	02H	0.87	
2B	24	51	08H	0.73	
2B	24	52	02H	0.54	
2B	24	56	02H	0.34	
2B	24	58	03H	0.26	
2B	24	62	03H	0.54	
2B	24	63	03H	0.5	
2B	24	65	02H	0.16	
2B	24	68	08H	0.17	
2B	24	71	05H	0.23	
2B	24	84	05H	0.26	
2B	25	17	02H	0.13	
2B	25	24	03H	0.46	
2B	25	29	02H	0.23	
2B	25	64	06H	0.42	
2B	25	79	08H	0.38	
2B	26	30	03H	0.62	
2B	26	39	03H	0.15	
2B	26	78	02H	0.35	
2B	27	46	06H	0.26	
2B	27	52	04H	0.54	
2B	27	53	03H	0.27	
2B	27	68	02H	0.23	
2B	28	41	02H	0.28	
2B	28	63	03H	0.27	
2B	28	67	03H	0.29	
2B	28	81	02H	0.16	
2B	29	20	03H	0.57	
2B	29	27	03H	0.58	
2B	29	31	05H	0.26	
2B	29	32	03H	0.14	
2B	29	32	05H	0.26	
2B	29	34	03H	0.38	
2B	29	35	04H	0.34	SAI
2B	29	37	03H	0.65	
2B	29	38	02H	0.44	MAI
2B	29	40	03H	0.82	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	29	41	02H	0.41	
2B	29	56	02H	1.08	
2B	30	16	04H	0.21	
2B	30	20	04H	0.19	
2B	30	27	02H	0.34	
2B	30	32	03H	0.19	
2B	30	50	04H	1.01	
2B	30	55	03H	0.63	
2B	30	59	04H	0.23	
2B	30	78	02H	0.34	
2B	30	78	04H	0.28	
2B	30	79	02H	0.31	
2B	30	81	03H	0.29	
2B	31	21	07H	0.24	
2B	31	23	02H	0.79	
2B	31	32	03H	0.41	
2B	31	32	05H	0.33	
2B	31	37	03H	0.51	
2B	31	39	02H	0.17	
2B	31	39	03H	0.6	
2B	31	48	02H	0.75	
2B	31	52	02H	0.64	
2B	31	71	05H	0.23	
2B	31	76	02H	0.44	
2B	31	78	02H	0.38	
2B	31	78	03H	1.04	
2B	32	16	08H	0.28	
2B	32	29	05H	0.23	
2B	32	31	02H	0.33	SAI
2B	32	53	02H	0.74	
2B	32	55	02H	0.63	
2B	32	55	05H	0.22	
2B	32	61	02H	0.27	
2B	32	61	05H	0.43	
2B	32	77	02H	0.37	
2B	33	31	07H	0.41	
2B	33	32	02H	0.13	
2B	33	37	04H	0.17	
2B	33	44	02H	0.43	

SG	Row	Col	Locn	2R18 Volts	Comment
2B	33	62	02H	0.86	
2B	34	18	08H	0.14	
2B	34	32	02H	0.24	
2B	34	35	03H	0.28	
2B	34	37	03H	0.43	
2B	34	48	02H	0.52	SAI
2B	34	48	03H	0.5	
2B	34	48	04H	0.28	
2B	34	51	02H	0.8	
2B	34	51	03H	0.41	
2B	34	57	02H	0.3	
2B	35	40	02H	0.31	
2B	36	25	05H	0.33	
2B	36	42	03H	0.24	
2B	36	58	05H	0.24	
2B	37	24	05H	0.11	
2B	37	32	03H	0.61	
2B	37	57	02H	0.35	
2B	37	57	05H	0.15	
2B	38	35	02H	0.55	
2B	38	63	03H	0.2	
2B	39	31	05H	0.22	
2B	39	33	03H	0.29	
2B	40	31	05H	0.2	
2B	40	42	02H	0.36	
2B	41	31	05H	0.27	
2B	41	52	08C	0.25	
2B	42	51	04H	0.25	
2B	44	48	02H	0.61	

Table A-3: DSI Indications for 2R18 in SG-C

SG	Row	Col	Locn	2R18 Volts	Comment
2C	2	78	03H	0.18	
2C	2	80	03H	0.19	
2C	2	85	03H	0.42	
2C	3	8	04H	0.36	
2C	3	9	06H	0.19	
2C	3	18	03H	0.32	
2C	3	35	05H	0.21	
2C	3	39	07H	0.37	
2C	3	45	02H	0.7	
2C	3	58	02H	0.42	
2C	3	60	02H	0.52	
2C	3	60	03H	0.34	
2C	3	64	02H	0.21	
2C	3	64	03H	0.61	
2C	3	80	02H	0.54	
2C	3	90	06H	0.35	
2C	3	93	04H	0.34	
2C	4	3	04H	0.32	
2C	4	26	03H	0.85	
2C	4	33	02H	0.4	
2C	4	39	07H	0.51	SAI
2C	4	48	02H	0.27	
2C	4	49	03H	0.53	
2C	4	69	03H	0.38	
2C	4	76	03H	0.22	
2C	5	6	03H	0.71	
2C	5	6	04H	0.16	
2C	5	7	02H	0.45	
2C	5	7	03H	0.82	
2C	5	15	03H	0.28	
2C	5	18	02H	0.38	
2C	5	19	02H	0.37	
2C	5	19	03H	0.27	
2C	5	62	02H	0.17	
2C	5	66	03H	0.52	
2C	5	71	02H	0.25	
2C	5	76	03H	0.47	
2C	5	86	08H	1.08	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	5	89	02H	0.65	
2C	6	23	02H	0.28	
2C	6	30	02H	0.23	
2C	6	30	03H	0.24	
2C	6	54	03H	0.58	
2C	6	55	02H	0.29	
2C	6	63	02H	0.57	
2C	6	78	03H	1.04	
2C	6	84	03H	0.25	
2C	6	92	04H	0.36	
2C	7	40	03H	0.73	
2C	7	40	04H	0.58	
2C	7	49	02H	0.59	
2C	7	49	03H	0.29	
2C	7	58	02H	0.58	
2C	7	67	02H	0.47	
2C	7	80	03H	0.23	
2C	8	2	08H	0.41	
2C	8	23	02H	0.65	
2C	8	24	02H	0.68	
2C	8	43	03H	0.27	
2C	8	63	06H	0.14	
2C	8	72	03H	0.28	
2C	8	84	03H	0.2	
2C	9	13	03H	0.14	
2C	9	20	04H	0.46	
2C	9	26	03H	0.26	
2C	9	30	02H	0.31	
2C	9	32	02H	0.76	
2C	9	35	02H	0.57	
2C	9	37	02H	0.58	
2C	9	38	03H	0.35	
2C	9	39	05H	0.27	
2C	9	41	02H	0.31	
2C	9	44	03H	0.25	
2C	9	45	05H	0.42	
2C	9	45	06H	0.25	
2C	9	47	02H	0.66	
2C	9	54	02H	0.43	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	9	54	04H	0.19	
2C	9	65	06H	0.22	
2C	10	8	02H	0.89	
2C	10	9	03H	0.24	
2C	10	10	02H	0.66	
2C	10	10	03H	0.52	
2C	10	18	04H	0.14	
2C	10	24	03H	0.34	
2C	10	36	02H	0.3	
2C	10	37	02H	0.81	
2C	10	38	07H	0.29	
2C	10	43	02H	0.39	
2C	10	44	02H	0.33	
2C	10	51	02H	1.22	
2C	10	51	05H	0.68	
2C	10	54	02H	0.76	
2C	10	54	03H	0.35	
2C	10	72	02H	0.38	
2C	10	72	03H	0.15	
2C	10	78	03H	0.44	
2C	11	7	02H	0.51	
2C	11	9	03H	0.54	
2C	11	17	02H	0.8	
2C	11	36	02H	0.46	
2C	11	42	02H	1.29	
2C	11	49	02H	0.62	
2C	11	49	03H	0.86	
2C	11	62	03H	0.63	
2C	11	70	03H	0.57	
2C	11	72	03H	0.31	
2C	11	88	05H	0.55	
2C	12	9	02H	0.64	
2C	12	30	02H	0.41	
2C	12	35	04H	0.13	
2C	12	55	02H	0.68	
2C	12	70	02H	0.36	
2C	12	70	03H	0.25	
2C	12	83	03H	0.1	
2C	13	32	02H	0.17	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	13	43	02H	0.25	
2C	13	43	03H	0.39	
2C	13	59	03H	0.36	
2C	13	63	02H	0.29	
2C	13	64	02H	0.68	
2C	14	29	04H	0.29	SAI
2C	14	38	02H	0.5	
2C	14	39	05H	0.19	
2C	14	50	02H	0.85	
2C	14	54	02H	0.44	
2C	14	59	03H	0.19	
2C	14	70	08H	0.2	
2C	15	5	04H	0.52	
2C	15	14	03H	0.33	
2C	15	35	02H	0.16	
2C	15	35	03H	0.56	
2C	15	38	04H	0.53	SAI
2C	15	39	02H	0.7	
2C	15	39	03H	0.45	
2C	15	61	02H	0.27	
2C	15	62	02H	0.26	
2C	15	80	03H	0.3	
2C	15	87	03H	0.27	
2C	16	15	03H	0.49	
2C	16	17	02H	0.35	
2C	16	46	02H	0.86	
2C	16	46	04H	0.3	
2C	16	55	06H	0.28	
2C	16	57	03H	0.4	
2C	16	63	02H	0.17	
2C	16	73	02H	0.39	
2C	17	9	04H	0.25	SAI
2C	17	14	04H	0.17	
2C	17	17	02H	0.28	
2C	17	18	02H	0.42	
2C	17	24	04H	0.11	
2C	17	26	03H	0.23	
2C	17	35	03H	0.83	SAI
2C	17	43	02H	0.51	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	17	48	02H	0.64	
2C	17	49	02H	0.49	
2C	17	50	03H	0.56	SAI
2C	17	61	02H	0.9	
2C	17	61	03H	0.28	
2C	17	63	02H	0.53	
2C	17	66	02H	0.19	
2C	17	67	02H	0.5	
2C	17	68	02H	0.33	
2C	18	15	06H	0.14	
2C	18	47	03H	0.36	
2C	18	48	02H	0.82	
2C	18	48	03H	0.72	
2C	18	48	04H	0.71	
2C	18	50	02H	0.25	
2C	18	51	02H	0.73	
2C	18	53	02H	0.73	
2C	18	54	02H	0.69	
2C	18	54	03H	0.51	
2C	18	55	02H	0.41	
2C	18	62	02H	0.5	
2C	18	62	03H	0.56	
2C	18	62	04H	0.16	
2C	18	67	02H	0.37	
2C	18	67	03H	0.58	
2C	18	73	03H	0.29	
2C	19	26	03H	0.25	
2C	19	29	02H	0.41	
2C	19	48	02H	0.48	
2C	19	48	03H	0.7	
2C	19	54	02H	0.38	
2C	19	57	04H	0.46	
2C	19	57	05H	0.63	
2C	19	79	02H	1.02	
2C	20	75	02H	0.36	
2C	20	76	02H	0.61	SAI
2C	20	76	03H	0.83	
2C	20	85	03H	0.22	
2C	21	18	02H	0.34	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	21	18	03H	0.36	
2C	21	25	04H	0.1	
2C	21	62	02H	0.42	
2C	21	67	07H	0.21	
2C	22	18	02H	0.41	
2C	22	18	05H	0.3	
2C	22	20	02H	1.3	
2C	22	24	03H	0.18	
2C	22	33	02H	0.38	
2C	22	61	03H	0.19	
2C	22	64	03H	0.33	
2C	22	75	04H	0.45	SAI
2C	22	77	03H	0.19	
2C	23	10	02H	0.35	
2C	23	28	03H	0.37	
2C	23	37	02H	0.71	
2C	23	39	02H	0.47	
2C	23	39	05H	0.44	
2C	23	42	02H	0.43	
2C	23	42	03H	0.5	
2C	23	69	03H	0.24	
2C	23	77	02H	0.35	
2C	24	34	08H	0.35	
2C	24	48	03H	0.68	
2C	24	50	02H	0.31	
2C	24	56	03H	0.69	
2C	24	57	02H	0.39	
2C	24	61	02H	0.76	
2C	24	63	04H	0.2	
2C	25	17	03H	0.3	
2C	25	26	04H	0.13	
2C	25	29	03H	0.41	plug
2C	25	31	02H	0.53	
2C	25	33	08H	0.53	
2C	25	34	02H	0.78	
2C	25	34	03H	0.52	
2C	25	34	05H	0.66	
2C	25	47	03H	0.53	
2C	25	47	08H	0.28	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	25	54	02H	0.23	
2C	25	60	02H	0.47	
2C	25	61	02H	0.55	
2C	25	62	04H	0.4	
2C	25	65	02H	0.62	
2C	25	74	02H	0.18	SAI
2C	25	76	02H	0.84	
2C	25	76	05H	0.33	
2C	25	79	02H	0.41	
2C	26	24	06H	0.2	
2C	26	38	05H	0.11	
2C	26	39	05H	0.45	
2C	26	42	02H	0.57	
2C	26	44	06H	0.2	
2C	26	65	03H	0.18	
2C	26	70	03H	0.67	
2C	26	72	08H	0.34	
2C	27	20	02H	0.61	
2C	27	22	02H	0.4	
2C	27	24	04H	0.26	
2C	27	30	02H	0.66	plug
2C	27	31	02H	0.82	
2C	27	60	02H	0.59	
2C	27	69	02H	0.25	
2C	27	76	03H	0.45	
2C	28	27	05H	0.35	
2C	28	35	02H	0.76	
2C	28	42	02H	0.33	
2C	28	42	04H	0.15	
2C	28	44	02H	0.34	
2C	28	50	03H	0.29	
2C	28	73	03H	0.19	
2C	28	85	02H	0.46	
2C	29	11	05H	0.49	
2C	29	26	05H	0.71	
2C	29	29	03H	0.96	
2C	29	37	02H	0.44	
2C	29	38	05H	0.23	
2C	29	43	03H	0.29	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	29	47	02H	0.41	
2C	29	48	05H	0.25	
2C	29	57	05H	0.35	
2C	29	63	05H	0.77	
2C	30	12	03H	0.25	
2C	30	24	02H	0.5	
2C	30	25	04H	0.12	
2C	30	31	03H	0.42	
2C	30	31	04H	0.38	
2C	30	41	02H	0.19	
2C	30	60	02H	0.66	
2C	30	61	02H	0.77	
2C	30	61	04H	0.38	SAI
2C	31	14	05H	0.22	
2C	31	17	04H	0.25	
2C	31	22	02H	0.23	
2C	31	29	04H	0.31	
2C	31	49	02H	0.28	
2C	31	60	02H	0.31	
2C	31	61	03H	0.51	
2C	31	61	04H	0.17	
2C	31	64	04H	0.5	SAI
2C	31	66	02H	0.65	
2C	31	66	05H	0.3	
2C	31	75	02H	0.17	SAI
2C	31	77	06H	0.25	
2C	31	81	02H	1.23	
2C	32	19	05H	0.25	
2C	32	25	03H	0.24	
2C	32	63	03H	0.35	SAI
2C	33	34	06H	0.32	
2C	33	60	07H	0.17	
2C	34	24	07H	0.12	
2C	34	39	05H	0.21	
2C	34	55	03H	0.14	
2C	34	58	02H	0.61	
2C	34	58	04H	0.22	
2C	34	58	05H	0.28	
2C	34	59	02H	0.74	

SG	Row	Col	Locn	2R18 Volts	Comment
2C	35	22	02H	0.2	
2C	35	34	03H	0.29	
2C	35	34	04H	0.16	
2C	35	38	07H	0.15	
2C	35	53	06H	0.21	
2C	36	20	03H	0.81	
2C	36	26	05H	0.58	
2C	36	27	05H	0.28	
2C	36	53	02H	0.97	SAI
2C	37	26	05H	0.07	
2C	37	35	03H	0.38	
2C	37	52	06H	0.15	
2C	38	42	05H	0.11	
2C	39	27	04H	0.41	
2C	40	25	03H	0.2	
2C	40	39	03H	0.11	
2C	40	53	04H	0.65	
2C	41	27	04H	0.32	
2C	41	44	04H	0.22	
2C	41	50	08H	0.18	
2C	42	32	04H	0.29	