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102-03822-JML/AKK/JRP
November 27, 1996

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References: 1) Letter 102-03748, dated August 6, 1996 from W. L. Stewart, Executive Vice President, Nuclear,
2) Letter Dated October 25, 1996, from James W. Clifford, Senior Project Manager USNRC to J. M. Levine, APS

Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Unit 3
Docket No. STN 50- 530
Response to Request for Additional Information Regarding the Unit 3 Cycle 6 Steam Generator Evaluation Report

The enclosure to this letter contains the Arizona Public Service Company (APS) response to the NRC request for additional information, Reference 2. This information is intended to support the information submitted in Reference 1 to support Unit 3 Cycle 6 operation for at least 15 1/2 months.

The safety significance associated with full cycle operation of Unit 3, until the next scheduled refueling outage, has been evaluated by APS. The results of the report indicate with high confidence that the conservative safety margins established in Regulatory Guide 1.121, " Bases for Plugging Degraded PWR Steam Generator Tubes," are maintained. In assessing the safety significance of the current conditions in the Unit 3 steam generators, APS has used, General Design Criteria 14 and 15 to assure that the design conditions of the reactor coolant boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences, and that there is an extremely low probability of abnormal leakage.

A001

APS has reviewed the consequences of previously analyzed accidents with respect to operation with existing Steam Generator tubing conditions. To further minimize the consequences of currently analyzed accidents, APS has taken measures to provide operations personnel with diagnostic tools and training. These measures include: event specific training of operations personnel with tube rupture events; improvements in leakage diagnostics via equipment upgrades including the implementation of N-16 monitors; and protocol upgrades to the Emergency Operating Procedures. These actions permit faster identification and isolation of the affected Steam Generator should a SGTR event occur. APS would be pleased to meet with the Staff at your convenience, should there be any questions or concerns.

Should you have any questions, please contact Scott A. Bauer at (602) 393-5978.

Sincerely,

JML/AKK/JRP/rh

Enclosure

cc: L. J. Callan
K. E. Perkins
J. W. Clifford
K. E. Johnston
I. Barnes

ENCLOSURE 1

APS Response to USNRC Request For Additional Information Related to Palo Verde Unit 3 Steam Generator Evaluation Report

APS Response to USNRC Request For Additional Information Related to Palo Verde Unit 3 Steam Generator Evaluation Report

Question 1

Provide a comparison of the actual steam generator tube inspection results to those which were predicted (or assumed) for such items as the number, length, depth, and voltage of the indications.

With respect to the comparisons between actual and projected values: (1) any discrepancies should be discussed [e.g., from Figure 4.3, the expected number of indications appeared to be under predicted by the methodology (i.e., the actual number of indications appear to exceed the 50 percent probability value for the expected number of indications)]; (2) differences between previous submittal' results should be addressed (i.e., Figure 4.3 does not match a similar figure provided in the January 5, 1996 letter); and (3) the frequency axes of these figures should be clarified.

Provide a comparison of the latest Unit 3 results to past Unit 3/Unit 2 results and compare these results to the structural limits.

Response

Based on the significant amount of information that has been submitted to the USNRC Staff regarding steam generator operation at PVNGS, APS provides the following summary in response to the Request for Additional Information (RAI) related to the Palo Verde Unit 3 Steam Generator Evaluation Cycle 6 Report. For this response, APS restates the precepts of the PVNGS Steam Generator Degradation Management Program:

1. All Stress Corrosion Cracking (SCC) defects are plugged on detection. No sizing repair limits are applied.

2. The best available inspection technology is utilized. The Plus Point probe has been used for inspection of the ARC region in all PVNGS steam generators since November 1994. Alternative measures such as Ultrasonic Testing (UT) and in-situ pressure testing have been utilized, when necessary.

3. A tube pull program removing and examining 31 tubes has been completed to benchmark the PVNGS eddy current (ECT) program, and for structural integrity verification.

4. Remedial measures to reduce the initiation and propagation rates of SCC defects have been implemented. These include: primary temperature reduction, chemical cleaning, molar ratio control, boric acid addition, reduced iron transport, and steam generator modifications to improve thermal hydraulic conditions.

5. The development of a Monte Carlo structural and leakage integrity model simulating the physical processes of crack initiation, crack growth, detection of degradation by eddy current inspection, and removal of degraded tubing from service. The model is performed for multiple cycles of operation. As such, benchmarking can easily be performed. Projections made in past applications for Units 1, 2, and 3 have proven to be accurate or conservative. At USNRC Staff request, APS has demonstrated benchmarks to the U2R4 tube rupture event in 1993 (Reference 2).

6. For a plug-on-detection program, APS has established structural and leakage integrity acceptance criteria based on Regulatory Guide 1.121, NUREG 0844, and guidance where applicable, from Generic Letter 95-05 and the Draft Steam Generator Rule and Regulatory Guide. Satisfaction of these criteria has been accomplished for all three PVNGS units since the Fall of 1993.

With respect to comparing Unit 3 actual steam generator inspection results to APS predictions, Figure 1 is provided to summarize key timeline information. The specific information requested by the USNRC Staff in the RAI has been provided in References 1, 3, 4, and 5. The following discussion clarifies any differences in information. As will be indicated, these differences are attributable to either the timeframe and purpose of Staff information requests, graphical software errors, or the difficulty in presenting complex statistical information. The response to these questions has been formatted as a condition monitoring assessment, as described in the draft Regulatory Guide supporting the proposed Steam Generator Rule.

A. Number of defects - Predicted verses actual observed

For Unit 3 Cycle 5, APS has provided to the USNRC Staff two (2) predictions and one (1) benchmarking verification. Figure 2 is a reprint from Reference 5, which provided the expected number of defects to be observed in U3R5 using 0.115 rotating pancake coil (RPC) detection techniques. During a meeting between the USNRC and APS on September 20, 1995, APS committed to update that prediction to account for the use of the Plus Point probe. Both industry and PVNGS experience indicated that detection improvements would be realized with the Plus Point probe, and therefore the number of small defects detected would increase. This is reflected in the projections, as the estimated mean increased from 58 (Figure 2) to 100 cracks (Figure 3 - reprinted). APS provided Figure 3 to the Staff via an October 16, 1996 letter (Reference 4). As reported in Reference 1, the total number of ARC region cracks detected by Plus Point in Unit 3 during U3R5 was 48. The projections provided in Figures 2 and 3 were clearly conservative. APS was purposely conservative in the Reference 1 assessment to account for the paucity of growth rate data from U3R4-U3M5 (See Figure 4). Additionally, further conservatism was included since model optimization of the crack initiation function during Cycle 5 was not performed. From a condition monitoring perspective, the analysis results have been verified.

The RAI discusses Figure 4.3 from Reference 1. Two questions have been raised by the USNRC Staff. The first question regards the differences in the histogram when compared to Figure 3. The Staff also questioned the apparent under-prediction of the 50% probability value. For

clarification purposes, Figure 4.3 is the result of benchmarking the Cycle 6 simulation model, and by definition, could not be used in a Cycle 5 condition monitoring assessment. As stated previously, the APS simulation model is a multiple cycle model, and therefore benchmarking is a critical part of simulation resolution and validation.

In developing a response to the RAI, APS has discovered that when the Figure 4.3 graphic was inserted into the Reference 1 report computer file, the "observed" arrow shifted to the right due to a software error. Please note that the arrow is only an annotation, and not part of the modeling process. As such, the histogram was not affected. As stated previously, the actual number of defects for U3R5 was reported as 48 defects not the 60 value shown in the original Figure 4.3. Figure 4.3, as well as Figures 4.1 and 4.2 of Reference 1, have been corrected and included in this package. The histograms demonstrated the validity of the benchmark. Overall, the model benchmarks were expected to improve over the pre-inspection projections based on the larger data set of paired Unit 3 RPC voltage data. Additionally, model optimization and better knowledge of the effect of the improved Plus Point probability of detection (POD) contributed to goodness of fit. Based on this assessment, APS concludes that the analysis methodology has provided consistent and conservative simulation of the corrosion rates and inspection and repair processes in the PVNGS steam generators.

The RAI also requested that the frequency axes of these histograms be clarified. As stated on page 20 of Appendix A in Reference 1, for calculation of probability of tube burst and the development of a distribution function for Regulatory Guide 1.121 structural exceedances, the simulation of the entire process (Figure 5) is performed 10,000 times. For benchmarking purposes, a shorter run of 1000 simulations of expected past outcomes is performed. The axis is therefore, the frequency of computer generated outcomes based on the 1000 benchmarking simulations.

B. Crack Length - Actual vs structural model assumptions

APS concludes that the crack lengths observed in U3R5 are bounded by the analyses contained in Reference 5 for Cycle 5, and Reference 1 for Cycle 6. As reported in previous information submitted to the USNRC Staff, the crack length distribution used in APS structural and leakage integrity analyses is not a projection, but an output distribution of actual ECT results. In 1994 (Reference 6), APS demonstrated via tube pulls, good correlation between structurally significant crack length (crack section where length and average depth over this length lead to minimum predicted burst pressure) and the ***0.115 pancake coil detected length***. Conversely, with the implementation of the Plus Point probe, our analysis showed that the shallow long crack contribution of the improved Plus Point POD was grossly overconservative in calculating tube burst probabilities. Consequently, a conservative distribution of Unit 2 pancake coil detected crack lengths has been utilized for the Unit 3 analyses, as indicated on page 30 of Reference 1.

APS has also found that end-of-cycle crack length distributions are very similar cycle to cycle and PVNGS unit to unit. From a condition monitoring perspective, APS performs a comparative assessment of the U3R5 Plus Point length distribution with a Unit 2 Plus Point distribution. As is shown in Figure 6, the Unit 2 Plus Point crack lengths bound the Unit 3 Plus Point inspection

results, with respect to the longest detected crack and mean value. Therefore it is reasonable to continue to use a Unit 2 pancake coil distribution for Unit 3 run time analyses. It is also worth noting, that the longest Plus Point detected defect in U3R5 of 9.5" in tube R103C142 was barely detectable and unmeasurable via the 0.115 pancake coil. It is estimated the crack is less than 30% through-wall. The structural limit for a defect of this length would be 64%.

C. Voltage/Depth - Predicted verses actual

Verification of model output with respect to observed defect size is performed three ways. The APS acceptance criteria for steam generator tube structural integrity requires a low probability of an end of cycle Regulatory Guide 1.121 exceedance. The probability of exceedance for Unit 3 Cycle 5 was 0.017 and is calculated to be less than 10^{-4} for Cycle 6. For criteria verification, ECT data is interrogated to determine by voltage, phase, and length, if any defects exceed the Regulatory Guide 1.121 allowable flaw size limits. If ECT data is insufficient or questionable, APS has employed alternative techniques such as UT or in-situ pressure testing to confirm structural integrity. The U3R5 results indicate that zero (0) exceedances were detected. The largest Unit 3 voltage recorded for a defect greater than 0.5 inches in length was 0.43 volts. Using the upper bound MRPC voltage/average depth correlation developed by APS, the limiting voltage would be 1.3 volts. The best estimate regression fit structural limit is 2.25 volts.

Validation of the APS leakage integrity model also serves as a check of the model input and output. Monitoring of operational leakage has been identified as performance criterion in the Draft Regulatory Guide supporting the anticipated Steam Generator Rule. The analysis contained in Reference 5 estimated the probability of a through-wall defect at 0.0035. As described in References 1, 2, and 5, APS employs strict Administrative controls on steam generator primary to secondary leakage. Shutdown of the unit is required if leakage exceeds 50 gallons per day (GPD). APS has also installed and/or upgraded the PVNGS leakage monitoring equipment, including the installation of N-16 monitors which would be particularly sensitive to leaks from upper bundle ARC region defects. No evidence of steam generator leakage was detected at the end of Cycle 5. None of the defects detected by ECT where estimated to be through-wall indications. Therefore, the leakage integrity criterion has been satisfied.

Finally, the defect growth rate probability distribution function is the dominant stochastic variable in APS run time analyses. For PVNGS steam generators, defect growth rates are computed using 0.115 pancake coil voltage growth statistics obtained from sequential inspections. While the uncertainty in the voltage/depth correlation may be attributed to different defect morphologies, the success of past APS predictions may be attributable to consistency in voltage response of a particular defect as it evolves from initiation to detection. In Reference 3, APS provided to the USNRC Staff, a projection of Unit 3 estimated voltage growth rate in volts/EFPY. The projection in Figure 7 (reprinted) indicates that 90% of the projected growth rates would be less than one (1) volt per EFPY. The actual results from U3R5 are tabulated in Tables 1 and 2 and presented graphically in Figure 8. The actual results indicate that voltage growth did not exceed 0.5 volts per EFPY for Unit 3 Cycle 5.

Based on the aforementioned information, APS concludes that the as-found condition of the Unit 3 steam generators, in U3R5, satisfies all structural and leakage performance design basis criterion for PVNGS. Furthermore, all projections for the end of Cycle 5 tubing conditions in Unit 3 have been conservatively confirmed. Based on the results of the U3R5 inspections as incorporated in the proven modeling methodology, and the defense-in-depth philosophy of the PVNGS Steam Generator Degradation Management Program, APS concludes as reported in Reference 1, that Unit 3 is safe for full Cycle 6 operation.

Question 2

Provide a summary of the results from in-situ pressure testing performed at Units 2 and 3.

Response

APS has not conducted in-situ testing in Unit 3, based on a defect population which has not warranted additional structural integrity verification other than the use of Plus Point MRPC. As indicated in Reference 2, APS has conducted in-situ testing in Unit 2 of upper bundle ARC region indications. In the Reference 2 submittal, APS listed these defects as greater than 3 volts. For the purpose of comparative assessment, the ECT voltage values have been re-evaluated using sizing techniques currently employed at PVNGS. As indicated, all tubes successfully passed the tests with no leakage. A summary of those results are provided below:

Steam Generator	Tube Number	0.115 RPC Volts	Test Pressure
SG 2-1	R118C95	2.85 volts	4260 psia
SG 2-1	R99C28	Volumetric - 66% TW	4260 psia
SG 2-2	R149C120	1.55 volts	4260 psia
SG 2-2	R146C121	1.90 volts	4260 psia
SG 2-2	R105C138	2.60 volts	4260 psia
SG 2-2	R144C105	2.68 volts	4260 psia
SG 2-2	R130C95	3.07 volts	4260 psia
SG 2-2	R117C44	1.76 volts 61% TW (bobbin)	4260 psia
SG 2-2	R110C143	Volumetric - 73% TW	4260 psia

As shown in the table, these results are consistent with the voltage-to-depth and burst correlations used in all of the run time analyses conducted by APS, and conservatively bound by a factor of three or more the largest voltage indication observed in U3R5.

Question 3

Discuss your plans for in-situ pressure testing and tube pulls in the next Unit 3 outage for monitoring degradation morphology and assessing inspection reliability.

Response

Currently, there are no plans for pulling tubes from Unit 3 during U3R6. Future tube pull plans at PVNGS are dependent on pursuit of any new repair criteria other than the present APS position of plug-on-detection, or changes in inspection techniques which represent reduced detection capability from the currently employed Plus Point probe. This position is re-evaluated on a cycle by cycle basis.

As part of APS's long term steam generator outage services contract, and the U3R6 outage scope description, in-situ test tooling is required to be available on an as-needed basis. As stated previously, all ECT data is evaluated to determine by voltage, phase, and length if any defects exceed allowable flaw size criteria. If ECT data indicates structural margins may be exceeded, or if the data is insufficient or questionable, APS will employ alternative techniques such as UT or in-situ pressure testing as necessary to confirm structural integrity.

References

1) *Unit 3 Cycle 6 Steam Generator Evaluation, July 1996*, submitted to the USNRC via letter 102-03748-WLS/AKK/JRP dated August 6, 1996

2) *Unit 2 Steam Generator Evaluation Report, August 1995*, submitted to the USNRC via letter 102-3465-WLS/SAB/JRP dated September 7, 1995

3) Letter APS to USNRC, *Steam Generator Evaluation,* 102-03579-WLS/SAB/JRP dated January 5, 1996

4) Letter APS to USNRC, *Unit 3 Refueling Outage 5 ARC Region Projections*, 102-03513-WLS/SAB/RJR dated October 16, 1995

5) *Unit 3 Steam Generator Evaluation, May 1995*, submitted to the USNRC via letter 102-03364-WLS/SAB/JRP dated May 19, 1995

6) *Status of PVNGS Steam Generator Activities, August 1994*, submitted to the USNRC via letter 102-03083-WLS/AKK/JRP dated August 11, 1994

Outage	EFPD	ARC Tubes Plugged SG 31/SG 32	MRPC Scope	Probe Type
U3M4	1558.1	0/0	220/SG BW1-1st VS	0.115 Pancake
U3R4	1608.4	1/16	400/SG 31 1530/SG 32 08H - 2nd VS	0.115 Pancake
U3M5	1773.9	8/15	2295/ SG 31 2730/ SG 32 08H - 2nd VS	0.115 Pancake for detection/ First time use of Plus Point Lengths and Voltages with Pancake
U3R5	2076.9	17/19	2810/ SG 31 2880/ SG 32 07H - 2nd VS	Plus Point MRPC - with 0.115 Pancake Lengths - Plus Point Voltages - Pancake

Unit 3 Timeline

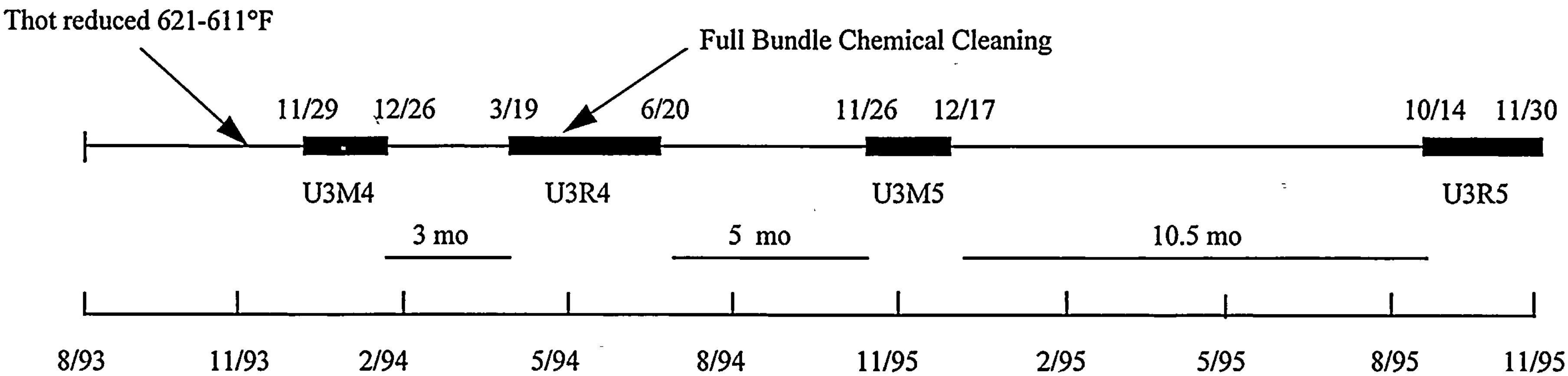
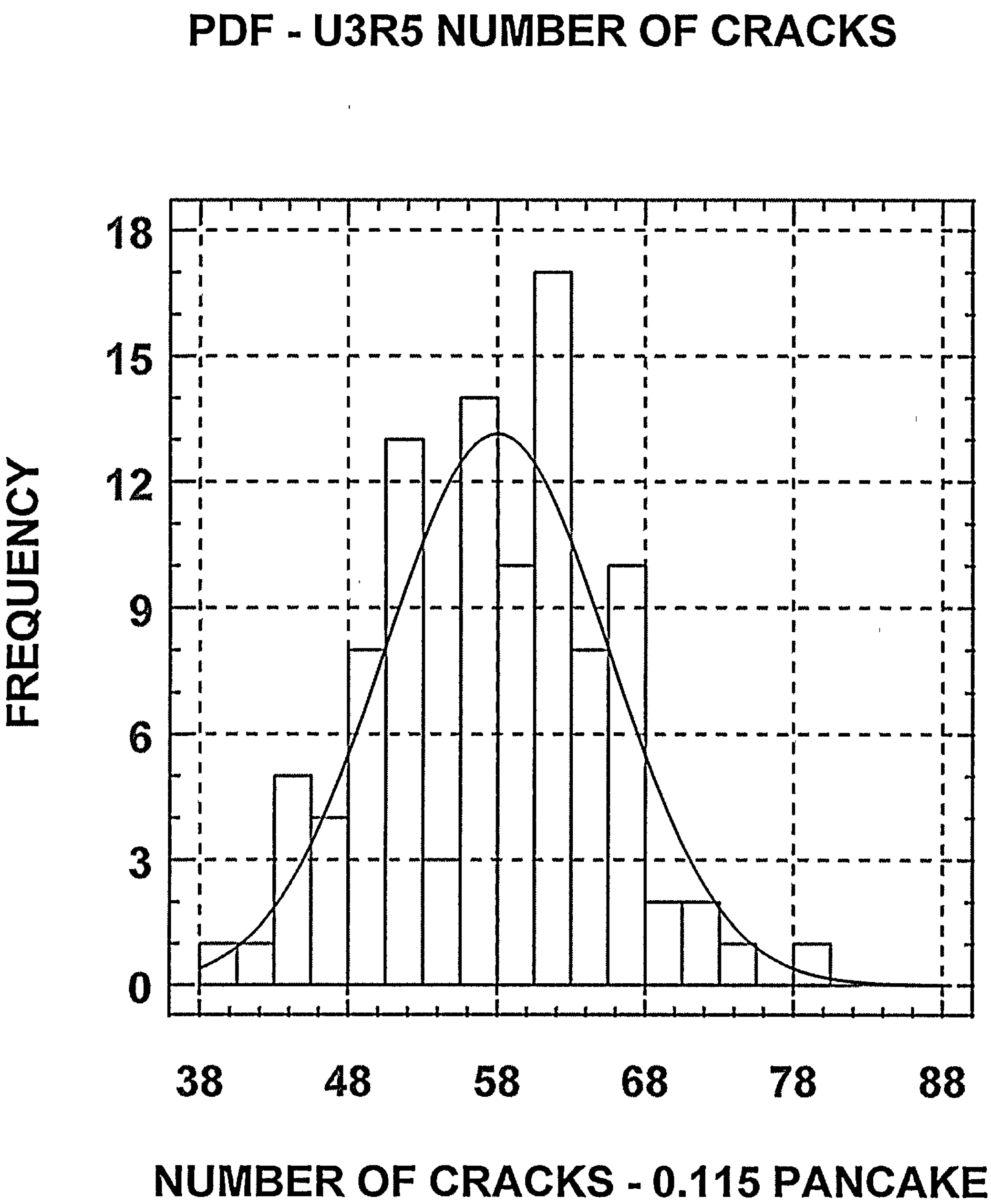


Figure 1



PDF - U3R5 NUMBER OF CRACKS
FREQUENCY
0
3
6
9
12
15
18
38
48
58
68
78
88
NUMBER OF CRACKS - 0.115 PANCAKE

Figure 2

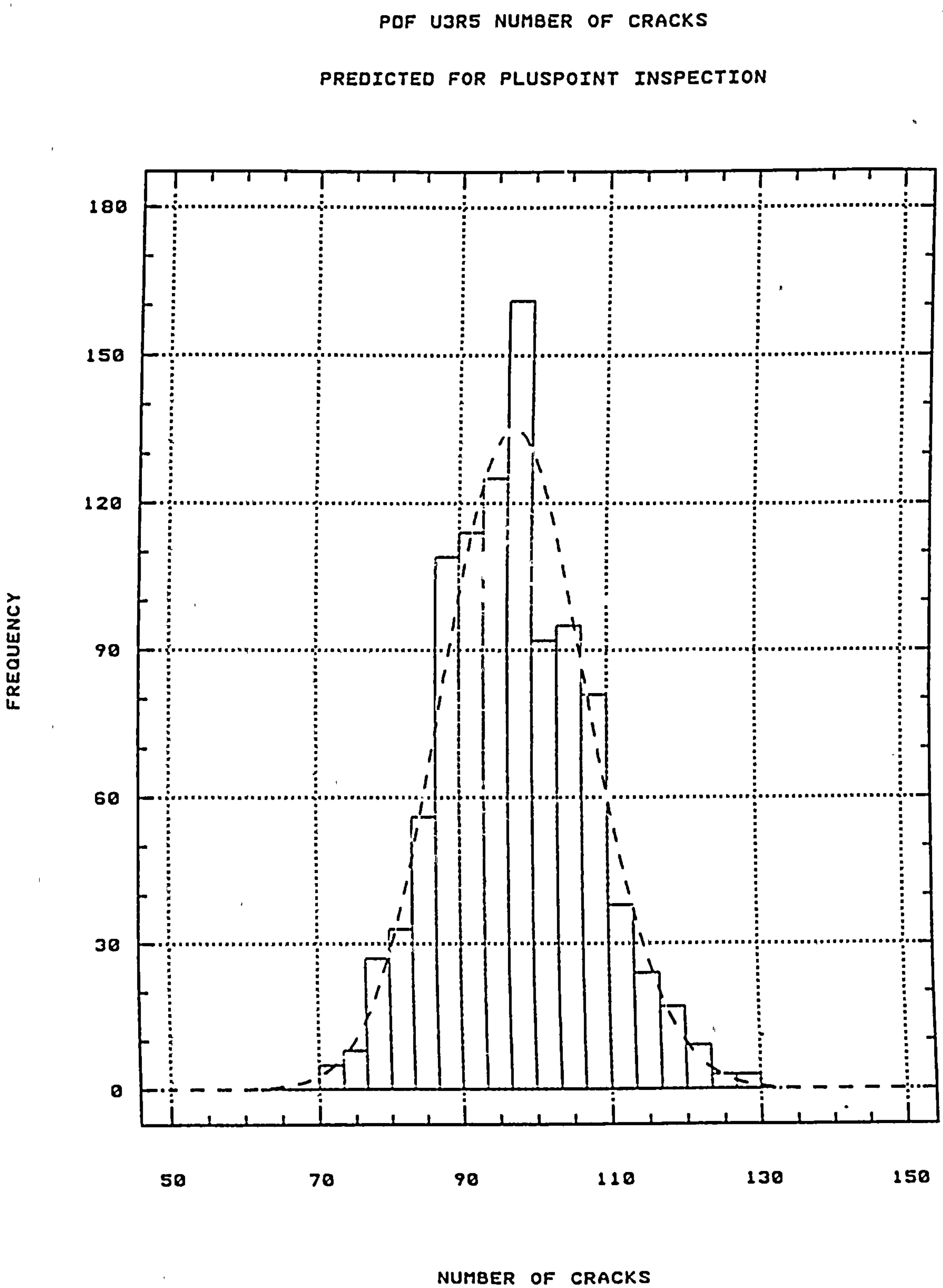

PDF U3R5 NUMBER OF CRACKS
PREDICTED FOR PLUSPOINT INSPECTION
FREQUENCY
180
150
120
90
60
30
0
50
70
90
110
130
150
NUMBER OF CRACKS

Figure 3

RPC VOLTAGE GROWTH VERSUS U3R4 VOLTAGE, 0.115" COIL

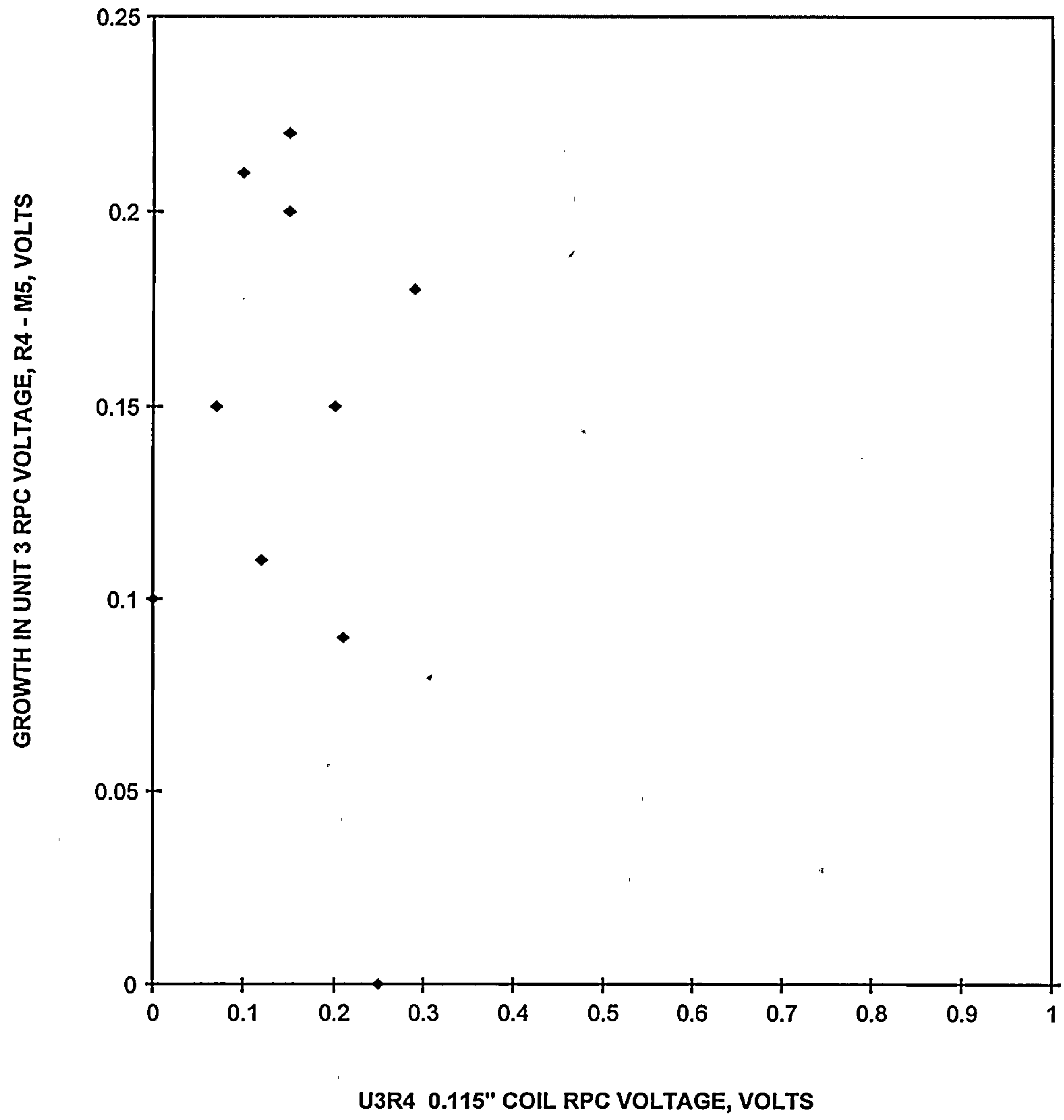


Figure 4

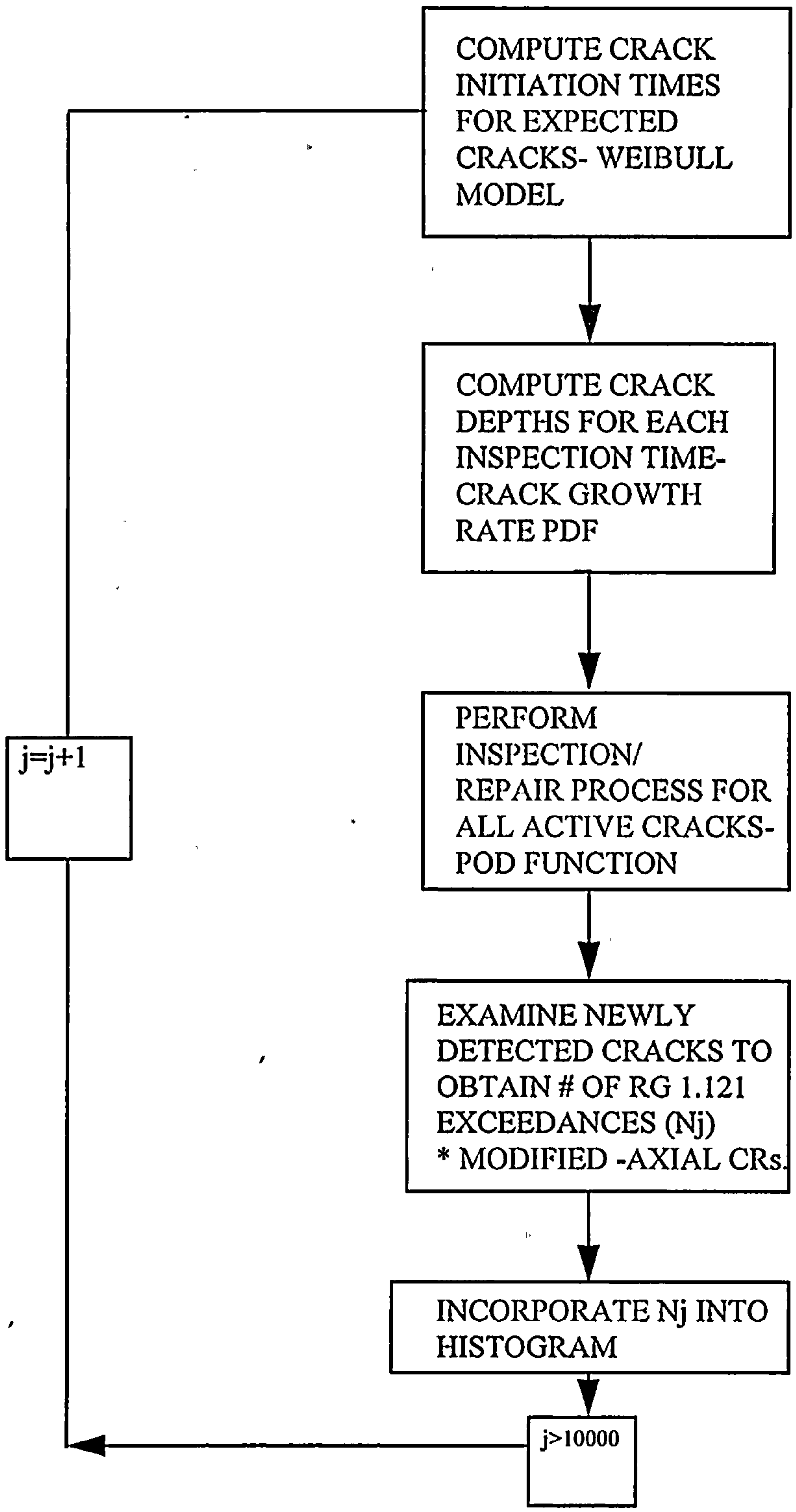


Figure 5 - SIMULATION SCHEMATIC FOR PROBABILISTIC MODEL

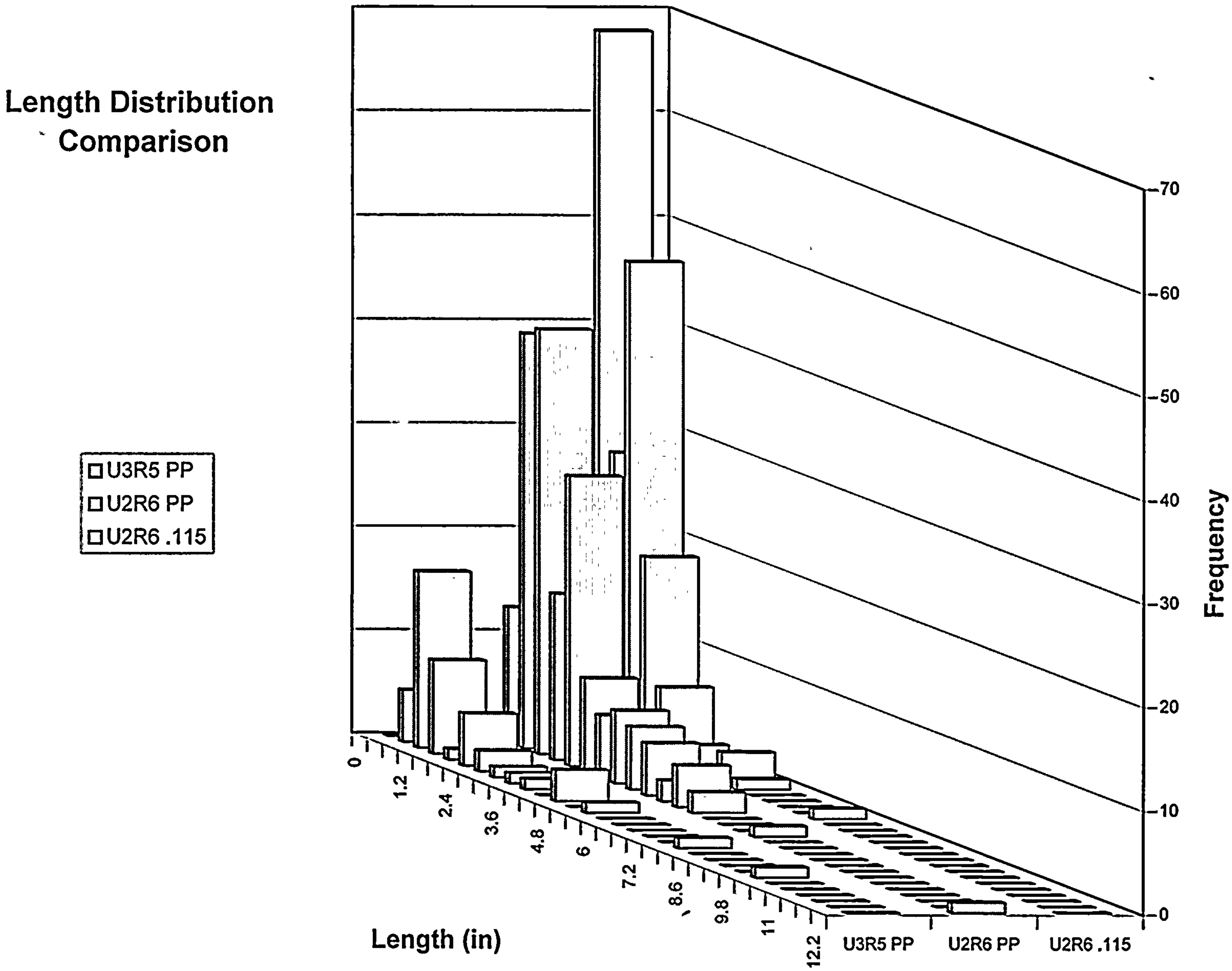


Figure 6

11/22/96 10:22 AM

PALO VERDE UNIT 3: ESTIMATED VOLTAGE GROWTH RATE DISTRIBUTION

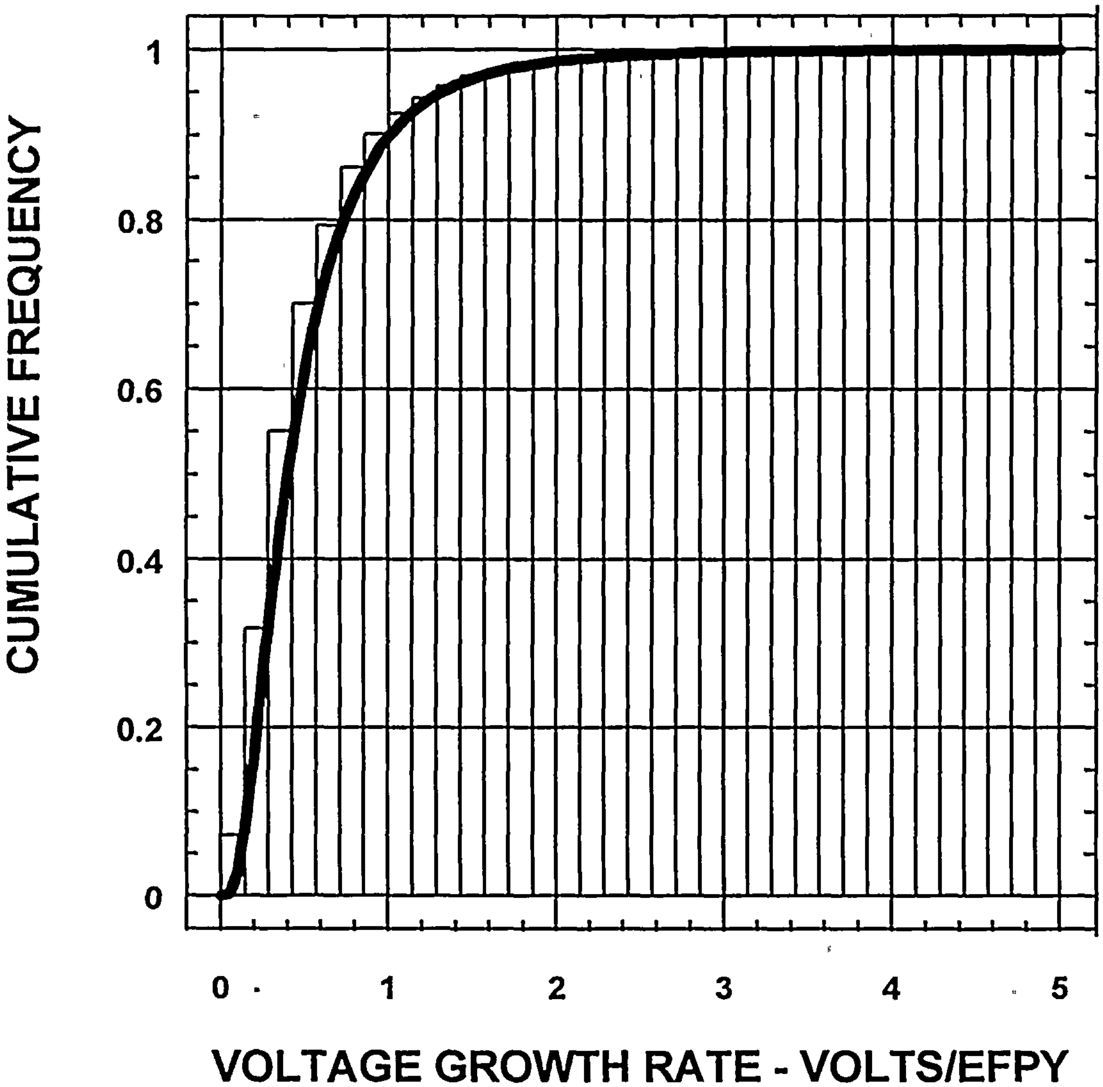


Figure 7

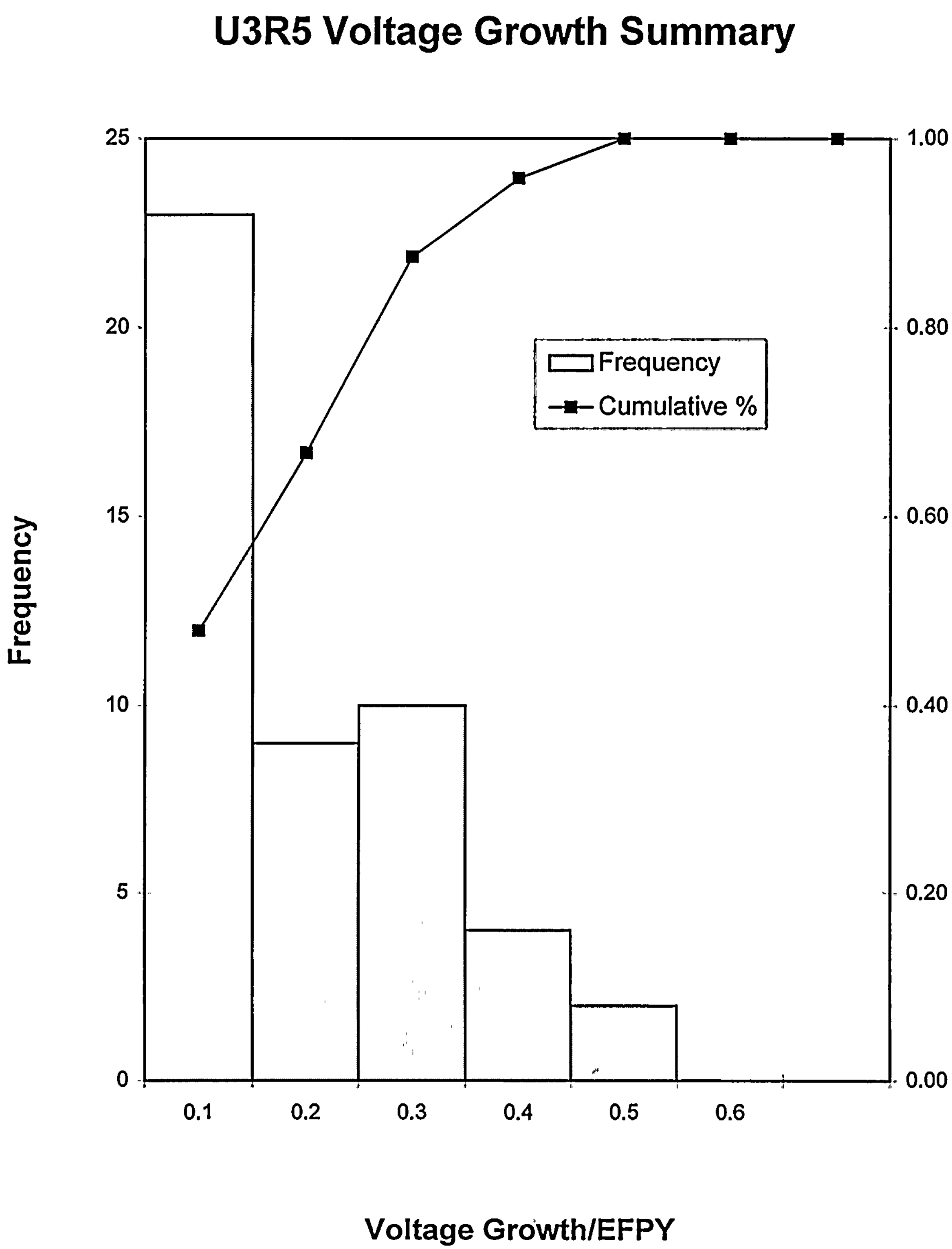


Figure 8

11/22/96 10:04 AM

ECT Summary Sheet - SG 3-1

SG	Number	Row	Line	Location	Length	Pancake Volts	Plus point Volts	ECT	Historical Length	Historical Pancake Volts	Historical PP Volts	DVDT
31	1	108	43	BW1 +2.33	1.8	0.23	0.56	SAI	NDD	0		0.28
	2	107	44	BW1 -0.26	0.9	0	0.64	SAI	0.6	0	0.52	0.00
	3	116	45	08H +38.84	3.5	0.27	0.54	SAI	1.4	0.19	0.41	0.10
	4	109	52	BW1 +0.73	2	0.4	0.47	SAI	1.2	0.2	0.36	0.24
	5	102	55	BW1 -0.57	2.2	0.31	0.67	SAI	1.9	0.22	0.67	0.11
	6	121	56	BW1 -0.76	1.2	0.4	0.65	SAI	0.6	0.17	0.55	0.28
	7	147	60	09H +7.97	0.7	0.25	0.31	SAI	None	None	None	0.30
	8	112	67	BW1 -0.90	1.8	0.35	0.85	SAI	0.8	0.2	0.73	0.18
	9	149	82	BW1+20.96	0.5	0	0.61	MAI	None	None	None	0.00
	10	149	82	BW1 +20.98	0.8	0	0.42	MAI	None	None	None	0.00
	11	149	92	BW1 +1.02	1.8	0.01	0.52	MAI	NDD	NDD	NDD	0.00
	12	149	92	BW1 +18.14	0.5	0.43	0.64	MAI	NDD	NDD	NDD	0.52
	13	149	92	BW1 +19.74	1	0.3	0.64	MAI	NDD	NDD	NDD	0.36
	14	132	95	09H +15.88	1.1	0.24	0.38	SAI	1	0.1	0.21	0.17
	15	137	98	BW1 +7.18	0.5	0	0.36	SAI	0.3	0	0.18	0.00
	16	135	100	BW1 -0.33	0.7	0	0.36	MAI	NDD	NDD	NDD	0.00
	17	135	100	BW1 +2.02	0.8	0.34	0.46	MAI	NDD	NDD	NDD	0.41
	18	119	132	08H +40.14	0.5	0	0.4	SAI	0.2	0	0.3	0.00
	19	103	140	08H +35.13	7.5	0.31	0.5	MAI	0.3	0.1	0.35	0.25
	20	103	140	BW1 +0.00	2.4	0.26	0.71	MAI	0.7	0.1	0.21	0.19
	21	103	142	08H +34.69	9.5	0.2	0.54	SAI	5	0.11	0.39	0.11
	22	103	144	08H +32.99	2.7	0.1	0.31	MAI	1.2	0	0.16	0.12
	23	103	144	08H +36.59	4.2	0.32	0.8	MAI	0.7	0.27	0.55	0.06
	24	103	144	BW1 -0.25	3	0.42	0.8	MAI	0.4	0.2	0.36	0.27

Table 1

11/22/96 10:07 AM

ECT Summary Sheet - SG 3-2

SG	Number	Row	Line	Location	Length	Pancake Volts	Plus point Volts	ECT	Historical Length	Historical Pancake Volts	Historical PP Volts	DVDT
32	1	96	37	VS2 -0.34	0.3	0.3	0.66	MAI	0.3	0.11	0.34	0.23
	2	96	37	VS2 +3.80	0.7	0.2	0.49	MAI	0.6	0.2	0.47	0.00
	3	106	39	BW1 +0.53	0.6	0	0.53	MAI	0.2	0	0.27	0.00
	4	106	39	VS2 +4.22	0.6	0.11	0.56	MAI	0.4	0.09	0.37	0.02
	5	101	42	VS2 +3.96	0.9	0.31	0.47	SAI	0.6	0.06	0.47	0.30
	6	102	45	VS2 +4.66	0.5	0.31	0.5	SAI	0.4	0.1	0.28	0.25
	7	102	49	BW1+21.54	0.5	0.16	0.27	MAI	0.3	0.09	0.18	0.08
	8	102	49	BW1+23.58	1.1	0.33	0.4	MAI	0.8	0.17	0.28	0.19
	9	96	51	BW1 -1.20	0.6	0	0.26	SAI	0.4	0	0.26	0.00
	10	104	51	08H +37.49	4.1	0.35	0.5	MAI	0.4	0.1	0.22	0.30
	11	104	51	BW1 +1.60	0.2	0.18	0.19	MAI	NDD	NDD	NDD	0.22
	12	96	53	BW1 +0.00	1.1	0.4	0.57	SAI	0.4	0.19	0.34	0.25
	13	133	56	VS1 +0.80	0.5	0.28	0.47	MAI	0.5	None	0.31	0.34
	14	133	56	VS1 +7.31	4.1	0.31	0.54	MAI	2.8	None	0.34	0.37
	15	102	57	BW1 -0.57	0.9	0.19	0.78	MAI	0.67	0	0.4	0.23
	16	102	57	BW1 +0.65	0.4	0.01	0.57	MAI	0.3	0	0.2	0.01
	17	105	60	08H +35.98	0.4	0.48	0.72	SAI	0.3	0.38	0.6	0.12
	18	128	89	BW1 +3.34	0.3	0.34	0.44	SAI	0.2	0.12	0.2	0.27
	19	112	97	08H +41.94	5	0.38	0.46	SAI	None	None	None	0.46
	20	142	97	BW1 +3.15	0.6	0.18	0.45	SAI	0.4	0.21	0.4	-0.04
	21	145	100	BW1 +2.34	1.6	0.01	0.23	MAI	NDD	NDD	NDD	0.01
	22	145	100	BW1 +19.65	1.8	0.2	0.23	MAI	NDD	NDD	NDD	0.24
	23	109	152	08H -0.17	0.9	0.08	0.57	SAI	NDD	NDD	NDD	0.09
	24	99	160	BW1 -1.23	0.7	0.01	0.48	SAI	0.5	0	0.47	0.01

Table 2

11/22/96 10:08 AM

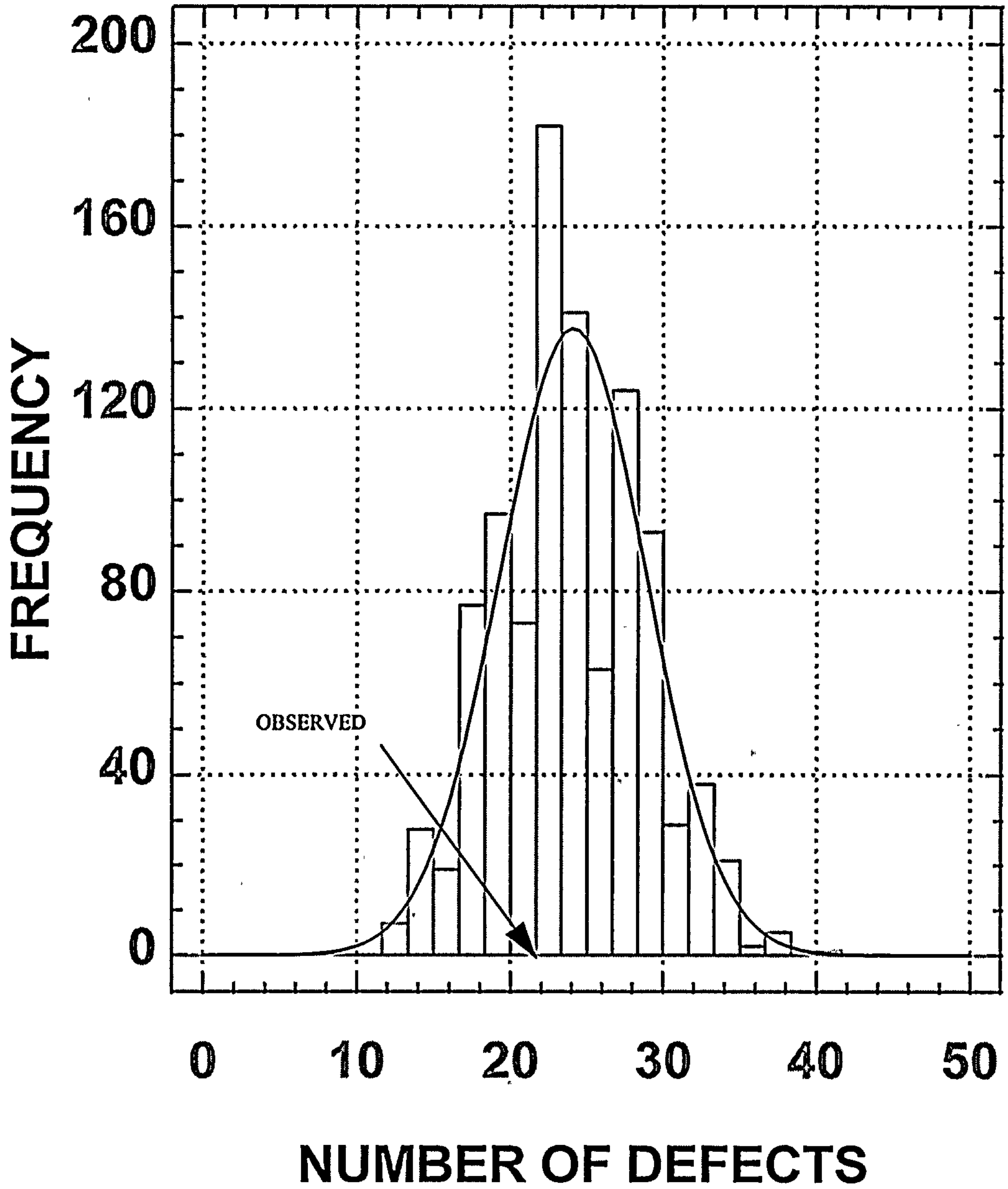


Figure 4.1 Predicted Number of Defects,U3R4

Corrected KMS 11/4/96

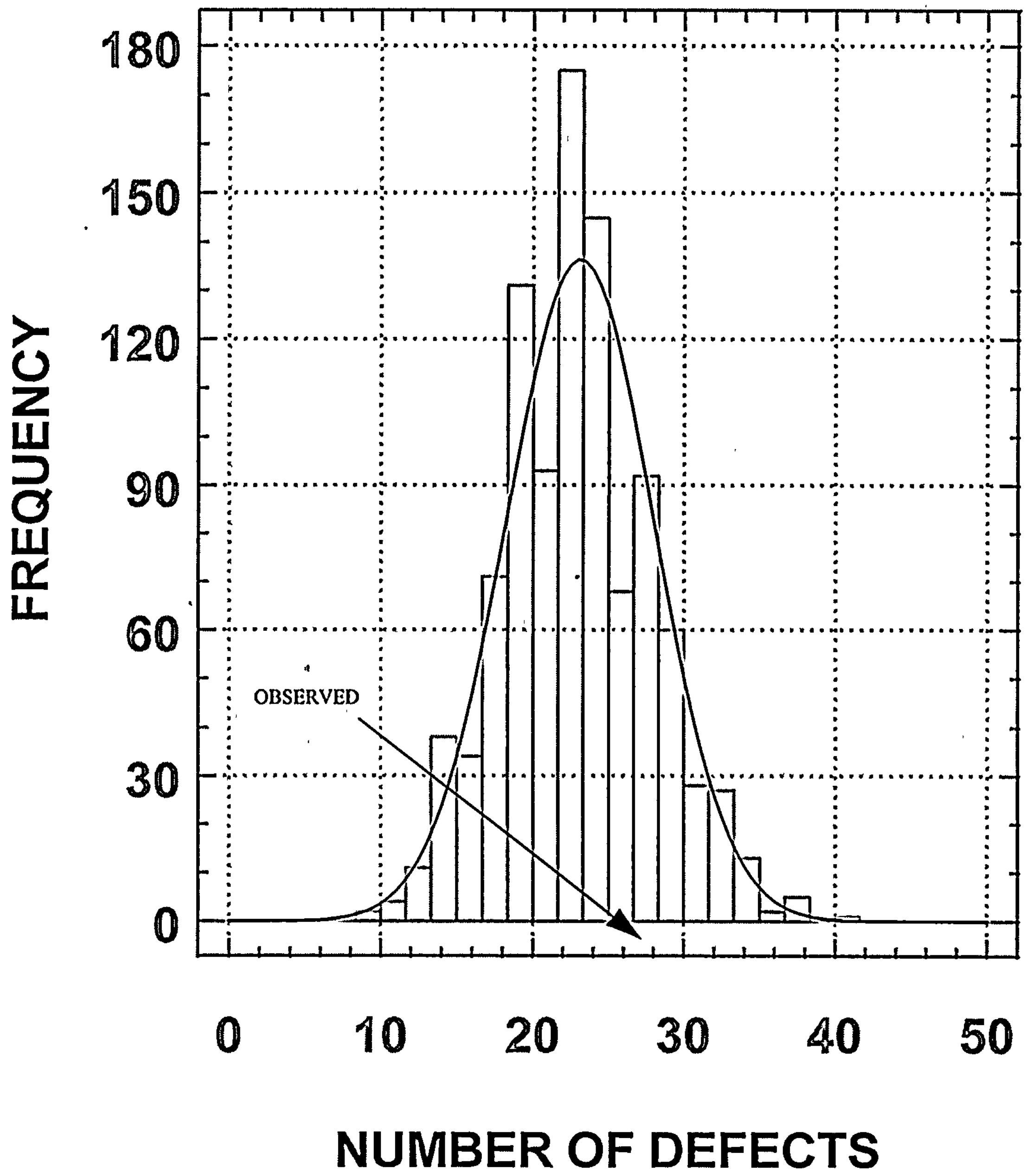


Figure 4.2 Predicted Number of Defects, U3M5

Corrected KMS 11/4/96

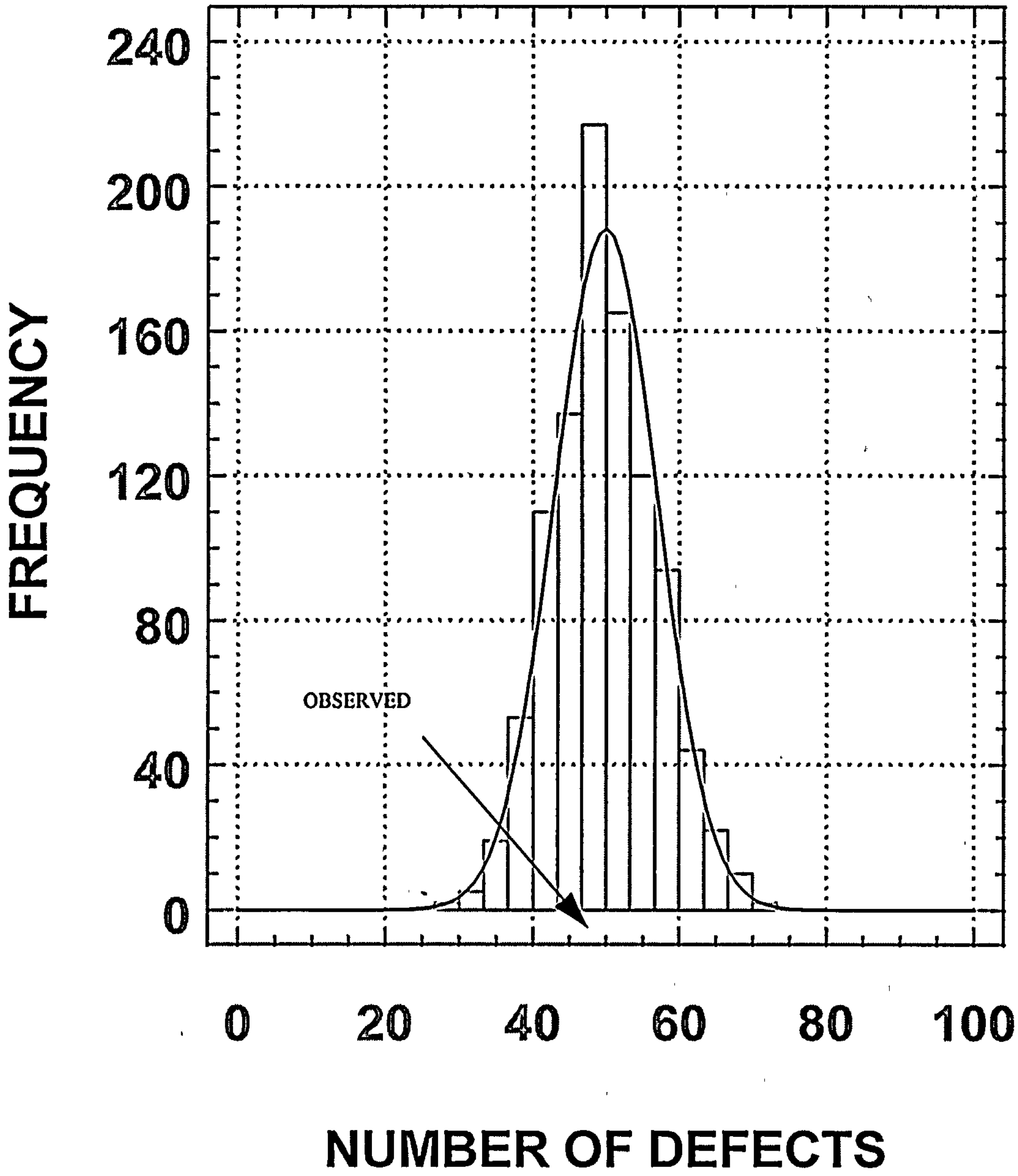


Figure 4.3 Predicted Number of Defects, U3R5

Corrected KMS 11/4/96