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CALCULATION TITLE PAGE

Client Florida Power Corporation	Page 1 of 15 Plus 3 Figures
Project Crystal River - Unit 3 (CR-3)	Task No. 102-071
Title CR-3 Analysis of S/N ECT Data for Steam Generator Tubes	Calculation No. RMC 102071-1

Preparer/Date	Checker/Date	Reviewer/Date	Rev. No.
R. M Carreitte 06APR94 [signature]	Kent W. Kennelly 06APR94 [signature]	[signature] 4-8-94	0

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RECORD OF REVISIONS

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Revision	Description
0	Initial Issue

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I. Purpose

The purpose of this calculation is to quantify statistically the S/N eddy current test data for the Crystal River - Unit 3 steam generator tubes.

The applicable data sets are:

1) Bobbin probe voltage data for first span tubes (600 KHz)

2) Bobbin probe voltage data for pulled tubes (Final Voltage)

3) Bobbin probe voltage data for other locations (Mix Voltage)

4) MRPC probe circumferential extent data for first span tubes

5) MRPC probe circumferential extent data for pulled tubes

6) MRPC probe circumferential extend data for other locations

7) MRPC probe axial extent data for first span tubes

8) MRPC probe axial extent data for pulled tubes

9) MRPC probe axial extent data for other locations

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II. Results

Pages 5 through 14 list the applicable data and list the number of samples (count), minimum, maximum, median and average values, and standard deviation for each data set. See table below.

Figure 1 is a plot of number of occurences versus probe voltage reading for the three locations; first span tubes, pulled tubes, and other locations

Figure 2 is a plot of number of occurences versus circumferential extent reading for the three locations

Figure 3 is a plot of number of occurences versus axial extent reading for the three locations

	Axial Extent (inches)			Circumferential (inches)			Voltage		
	Avg	Std Dev	Count	Avg	Std Dev	Count	Avg	Std Dev	Count
First Tube Span	0.12	0.05	54	0.16	0.06	54	0.59	0.21	200
Pulled Tubes	0.14	0.03	22	0.18	0.04	22	0.67	0.26	20
Other Locations	0.12	0.05	43	0.16	0.05	43	0.74	0.41	462

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III. Methodology & Calculation

1. Eddy current data quantified in this calculation were obtained from Florida Power Corporation.

2. Microsoft Excel Version 5.0 was used to calculate median, mean (average), and standard deviation and find minimum and maximum values

3. Mean or average values were calculated as follows:

$$\bar{x} = \frac{\Sigma x_i}{N}$$ where N is number of samples (the count)

4. Median is the value which lies in the middle of the data set

5. Standard deviation values were calculated as follows:

$$\text{std dev} = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{N-1}}$$

6. Results were checked on a sample basis using a Hewlett Packard hand calculator.

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Crystal River Unit 3
May 1992 Eddy Current Voltage Readings
Data for First Span Tubes - Volts 600 kHz S/N

0.66	0.79	0.70	0.45	0.35	0.82
1.19	0.37	0.71	0.50	0.41	0.55
0.30	0.20	0.67	0.52	0.62	0.78
0.72	0.42	0.61	0.40	0.58	0.79
0.44	0.64	0.61	0.53	0.64	0.39
0.36	0.52	0.82	0.46	0.56	0.53
0.29	0.34	0.58	0.57	0.74	0.81
0.42	0.47	0.14	0.56	0.69	0.92
0.28	1.39	0.51	0.50	0.52	0.52
0.46	0.31	0.63	0.46	0.54	0.93
0.54	0.52	0.45	0.47	0.88	0.59
0.42	0.50	0.47	0.60	0.79	0.45
0.45	1.13	0.60	0.64	1.13	0.49
0.32	0.41	0.41	0.55	0.24	0.50
0.43	0.79	0.58	0.47	0.52	0.49
0.53	0.51	0.35	0.34	0.43	0.43
0.65	1.00	0.50	1.32	0.43	0.57
0.49	0.50	0.72	0.76	0.59	0.85
0.54	0.66	0.62	0.65	0.55	0.59
0.47	0.52	0.46	0.88	0.52	0.76
0.62	0.27	0.83	0.53	0.40	
0.63	0.63	0.44	0.36	0.47	
0.43	0.65	0.66	0.70	0.60	
0.65	0.63	0.75	0.47	0.55	
0.43	0.78	0.60	0.39	0.55	
0.66	0.55	0.45	0.59	0.39	
0.35	0.43	0.71	0.63	0.51	
0.57	0.30	0.89	0.58	0.57	
0.49	0.61	0.54	0.37	0.90	
0.39	0.79	0.43	1.20	0.78	
0.52	0.73	0.47	0.44	0.77	
0.56	0.69	0.60	0.79	0.91	
0.48	0.28	0.80	0.90	0.39	
1.51	0.67	0.37	0.73	0.85	
1.01	0.79	0.64	0.82	0.81	
0.66	0.40	0.77	0.47	0.83	

Count	200
Min Value	0.14
Max Value	1.51
Median	0.55
Average	0.59
Std Dev	0.21

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Crystal River Unit 3

May 1992 Eddy Current Voltage Readings

Data For Tubes Other Th[illegible]st Span - Mixed Volts S/N

0.98	0.82	0.74	[illegible]29	1.56	0.82	0.43	0.45	0.60
3.10	0.55	0.77	0[illegible]	1.61	0.78	0.57	1.07	0.68
1.09	0.73	0.64	0.46	0.66	0.62	0.47	1.08	0.56
1.64	1.42	0.76	0.51	0.91	0.57	0.53	0.84	0.89
0.81	0.96	0.48	0.73	0.80	0.53	0.50	0.31	0.54
0.77	0.63	0.59	0.48	1.96	2.41	0.76	0.64	0.31
1.45	0.48	1.16	0.53	1.94	0.43	0.68	0 47	0.47
1.38	0.73	0.58	0.70	1.09	0.79	0.53	0.45	0.55
0.71	0.61	0.87	0.79	0.52	0.95	0.49	0.53	1.33
0.63	1.09	0.84	0.40	0.63	0.67	0.82	1.22	0.59
1.49	0.44	0.42	0.66	0.67	0.64	0.99	0.79	0.89
0.77	0.49	0.43	0.43	0.56	0.66	0.73	0.74	1.48
0.63	0.55	0.44	2.07	0.60	1.00	0.78	0.88	0.65
0.55	0.24	0.37	0.68	0.56	0.62	0.47	0.68	0.45
0.54	1.11	0.55	0.64	0.48	1.28	0.63	0.64	0.49
0.93	0.65	0.50	0.57	0.65	0.32	0.41	0.99	1.15
0.89	0.81	0.35	1.13	0.56	0.57	0.49	0.74	0.43
0.43	0.64	1.13	0.76	1.17	0.54	0.70	0.63	0.56
0.58	0.66	0.95	0.58	0.61	0.57	0.65	1.02	0.60
1.64	0.68	1.06	0.46	0.48	0.90	1.25	0.75	0.74
0.41	0.52	0.97	0.95	0.77	0.89	0.36	0.63	0.46
0.44	0.64	0.70	0.53	0.55	0.66	0.68	0.97	0.43
1.06	0.71	0.50	1.21	0.60	0.52	0.59	0.37	0.57
0.58	0.64	0.85	0.39	0.51	0.81	0.71	1.11	0.43
0.92	0.86	1.16	0.62	0.93	0.81	0.61	0.49	0.90
0.79	0.51	0.68	1.02	0.48	0.51	1.37	0.65	0.84
0.46	0.63	0.80	0.70	0.62	0.57	0.48	0.64	0.34
1.07	0.67	1.02	0.87	0.61	0.80	0.74	0.54	0.39
1.53	0.66	0.53	5.58	0.60	0.66	1.05	0.56	0.87
0.54	1.04	0.80	2.02	0.49	0.42	0.67	0.63	0.34
0.80	0.56	0.89	1.83	1.26	0.57	0.47	0.82	0.68
0.39	0.75	0.61	1.06	0.69	0.50	0.86	1.12	1.67
0.75	0.54	1.33	0.52	0.44	0.61	0.66	0.38	0.55
0.61	0.92	0.36	1.24	2.38	1.69	0.51	0.72	0.53
1.07	0.57	0.84	0.94	0.69	0.85	0.44	0.39	0.47
0.40	0.71	0.61	0.98	1.00	0.56	0.59	0.71	0.38

Count 324

Continued .....

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Crystal River Unit 3
May 1992 Eddy Current Voltage Readings
Data For Tubes Other Than First Span - Mixed Volts S/N (Continued)

0.76	0.83	0.48	0.70	0.50
0.55	0.88	0.61	0.64	0.69
1.04	0.56	0.61	0.68	0.35
0.67	0.53	0.49	0.05	0.62
0.59	1.04	0.31	0.56	0.20
0.79	0.62	0.74	0.92	0.96
0.88	0.46	1.01	0.62	0.38
0.50	1.32	0.43	0.58	0.79
0.88	1.11	0.61	0.44	0.35
0.77	0.87	0.37	0.13	0.60
0.47	1.45	0.89	0.66	0.62
0.55	0.82	0.48	0.55	0.75
0.47	0.58	0.84	0.22	0.80
0.61	0.78	0.74	0.60	0.75
0.50	0.44	0.79	0.81	
0.63	0.41	0.44	0.44	
0.75	1.02	0.44	0.41	
1.05	1.00	0.79	0.42	
0.62	0.53	0.83	0.70	
0.89	0.86	0.84	0.51	
0.71	0.41	1.35	0.34	
0.84	1.08	0.63	0.42	
0.48	0.28	0.49	0.63	
0.77	0.86	0.75	0.71	
0.83	0.52	0.48	0.57	
0.61	0.46	0.70	1.51	
0.38	0.92	0.65	0.69	
0.54	1.69	0.63	0.73	
0.40	0.73	0.46	0.57	
0.58	0.77	0.74	0.28	
0.98	0.60	0.31	1.04	

Count	462
Min Value	0.05
Max Value	5.58
Median	0.64
Average	0.74
Std Dev	0.41

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Crystal River Unit 3
May 1992 Eddy Current Voltage Readings
Data for Pulled Tubes - Final Volts S/N

0.47
0.52
1.03
0.30
0.63
0.88
0.89
1.08
0.85
0.34
0.31
0.84
0.34
0.48
0.98
0.95
0.79
0.60
0.55
0.57

Count	20
Min Value	0.30
Max Value	1.08
Median Value	0.62
Mean Value	0.67
Std Deviation	0.26

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe
Circumferential Extent Readings For First Span Tubes

0.15	0.17
0.12	0.06
0.15	0.19
0.17	0.17
0.21	0.09
0.15	0.16
0.20	0.12
0.20	0.13
0.15	0.28
0.13	0.00
0.17	0.17
0.21	0.16
0.21	0.22
0.16	0.22
0.14	0.15
0.14	0.23
0.18	0.19
0.18	0.40
0.15	
0.14	
0.00	
0.14	
0.18	
0.00	
0.17	
0.17	
0.19	
0.18	
0.07	
0.17	
0.20	
0.19	
0.18	
0.15	
0.19	
0.13	

Count	54
Min Value	0.00
Max Value	0.40
Median	0.17
Average	0.16
Std Dev	0.06

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe Readings
Circumferential Extent Readings For Pulled Tubes

0.20
0.17
0.17
0.19
0.14
0.20
0.19
0.19
0.19
0.17
0.19
0.25
0.18
0.10
0.18
0.14
0.11
0.19
0.13
0.15
0.19
0.25

Count	22
Min Value	0.10
Max Value	0.25
Median	0.19
Average	0.18
Std Dev	0.04

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe Readings
Circumferential Extent Readings For Tubes Other Than First Span

0.12	0.18
0.18	0.18
0.14	0.16
0.16	0.17
0.05	0.13
0.19	0.21
0.22	0.23
0.15	0.13
0.10	0.08
0.09	
0.19	
0.17	
0.20	
0.18	
0.14	
0.18	
0.14	
0.13	
0.15	
0.15	
0.12	
0.16	
0.00	
0.14	
0.22	
0.12	
0.22	
0.21	
0.18	
0.20	
0.20	
0.16	
0.10	
0.18	

Count	43
Min Value	0.00
Max Value	0.23
Median	0.16
Average	0.16
Std Dev	0.05

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe Readings
Axial Extent Readings For First Span Tubes

0.18	0.08
0.14	0.08
0.04	0.11
0.16	0.11
0.04	0.11
0.22	0.12
0.12	0.15
0.11	0.07
0.07	0.14
0.14	0.00
0.15	0.18
0.11	0.11
0.15	0.18
0.18	0.17
0.08	0.08
0.14	0.15
0.11	0.15
0.14	0.31
0.11	
0.08	
0.00	
0.10	
0.04	
0.08	
0.14	
0.05	
0.06	
0.17	
0.07	
0.15	
0.14	
0.14	
0.07	
0.16	
0.11	
0.14	

Count	54
Min Value	0.00
Max Value	0.31
Median	0.12
Average	0.12
Std Dev	0.05

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe Readings
Axial Extent Readings For Pulled Tubes

0.15
0.19
0.19
0.14
0.11
0.16
0.19
0.15
0.15
0.15
0.15
0.15
0.19
0.08
0.16
0.11
0.13
0.11
0.11
0.12
0.15
0.11

Count	22
Min Value	0.08
Max Value	0.19
Median	0.15
Average	0.14
Std Dev	0.03

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Crystal River Unit 3
May 1992 Eddy Current MRPC Probe Readings
Axial Extent Readings For Tubes Other Than First Span

0.12	0.15
0.12	0.12
0.12	0.18
0.11	0.11
0.15	0.10
0.12	0.12
0.16	0.29
0.14	0.07
0.08	0.08
0.05	
0.14	
0.11	
0.12	
0.31	
0.10	
0.12	
0.07	
0.10	
0.15	
0.10	
0.05	
0.15	
0.01	
0.11	
0.21	
0.12	
0.15	
0.13	
0.14	
0.13	
0.14	
0.07	
0.08	
0.14	

Count	43
Min Value	0.01
Max Value	0.31
Median	0.12
Average	0.12
Std Dev	0.05

Figure 1 - Crystal River Unit 3
Bobbin Probe - Voltage Readings

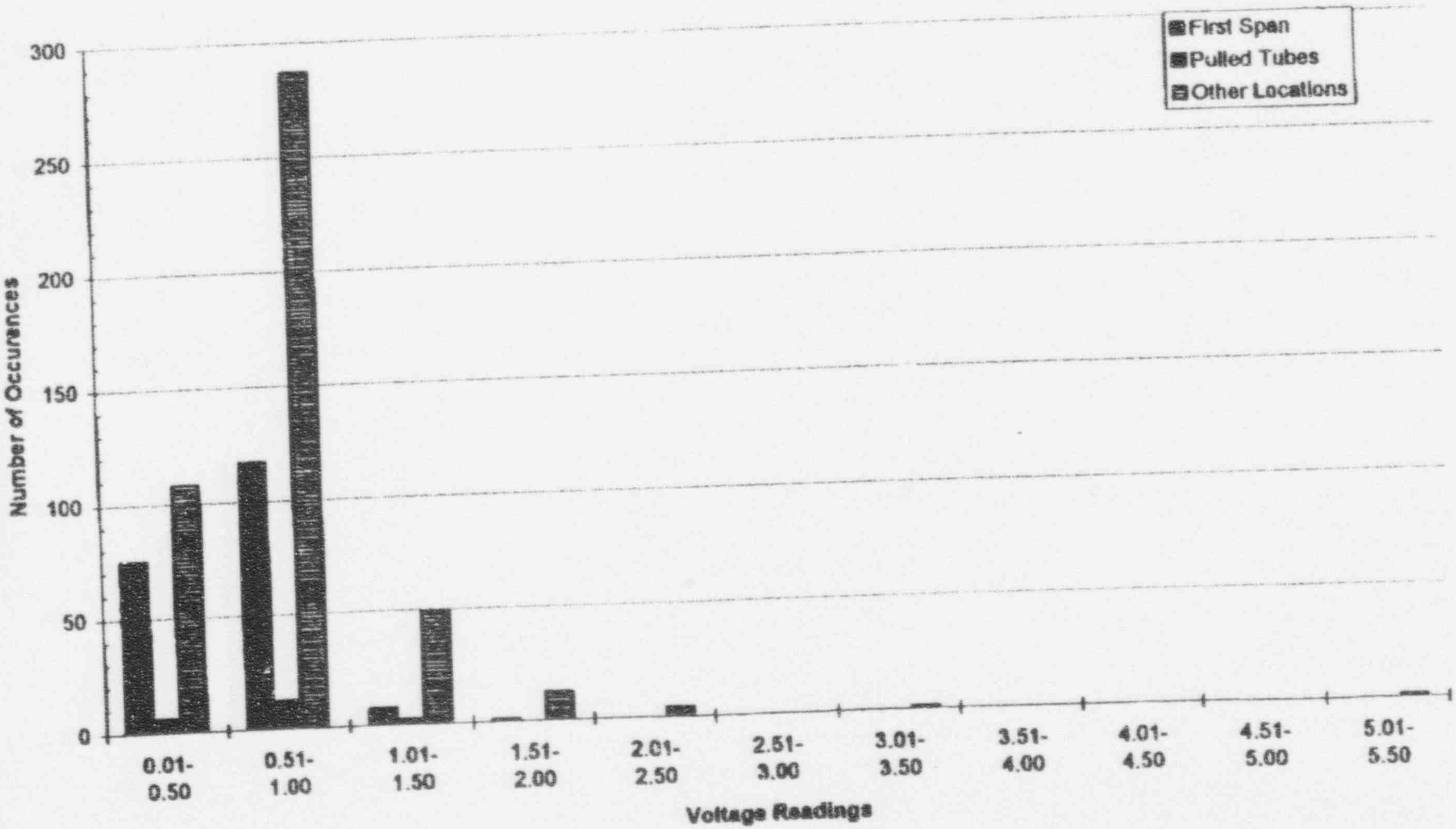

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Figure 2 - Crystal River Unit 3
MRPC Probe - Circumferential Extent

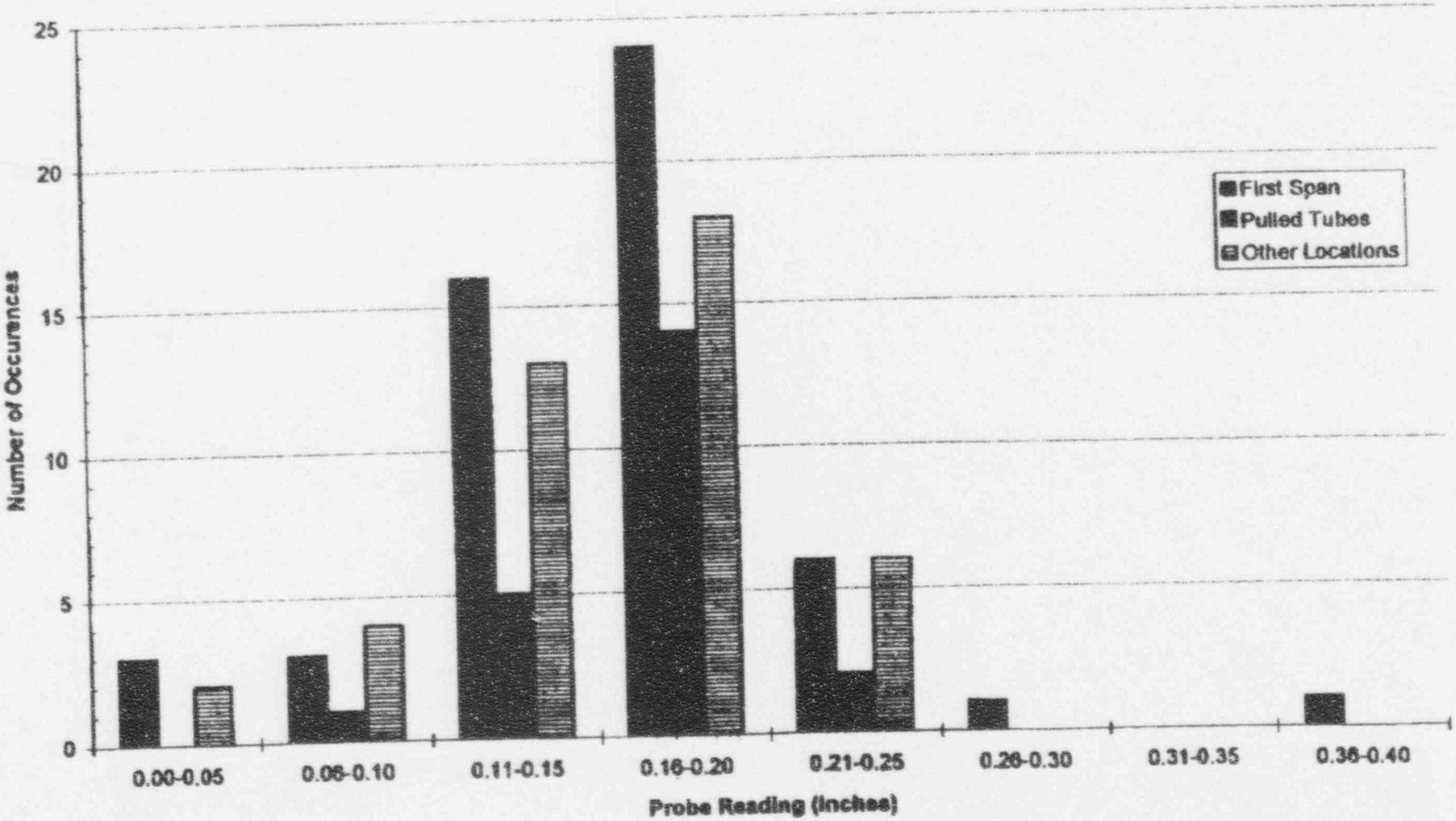

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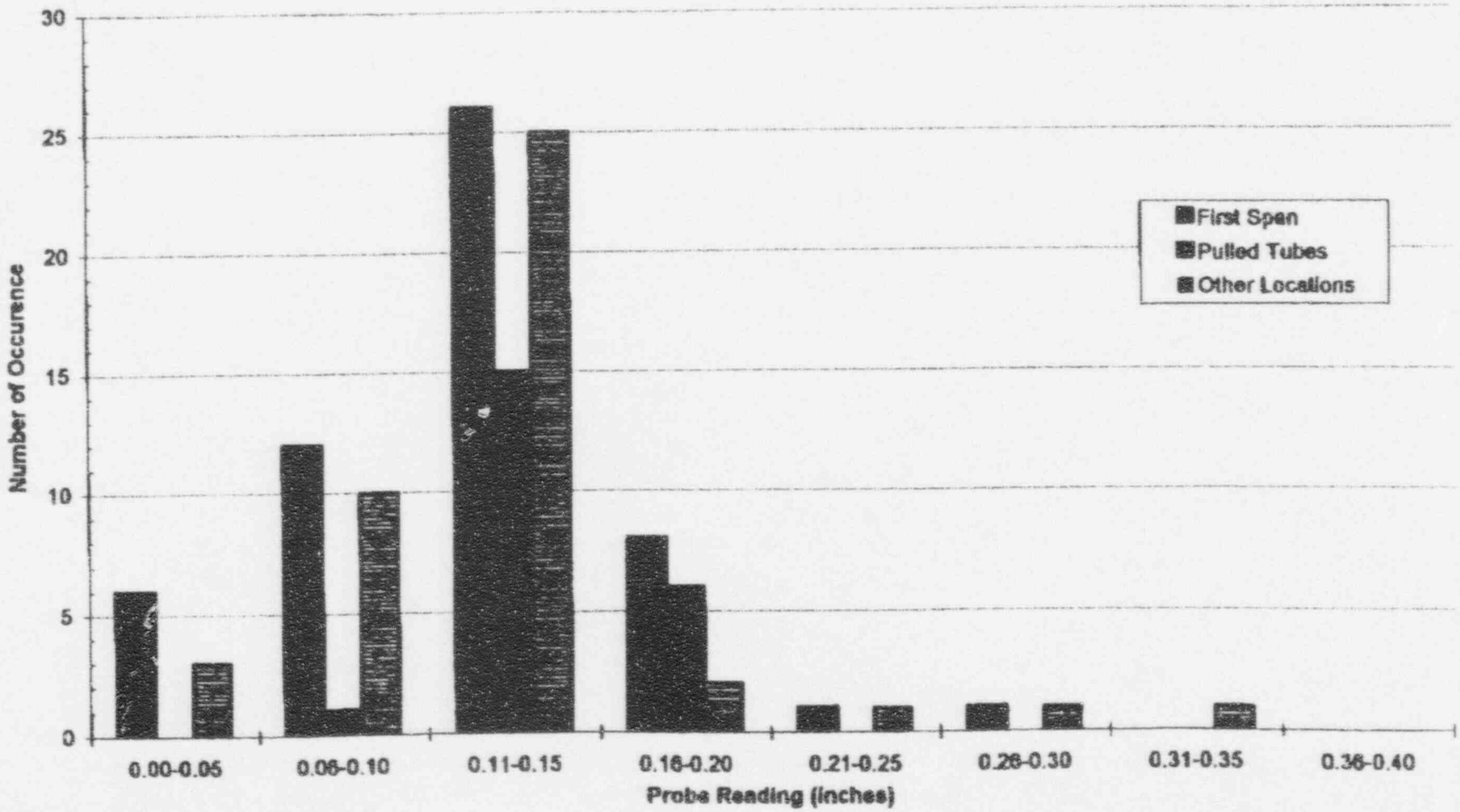
Figure 3 - Crystal River Unit 3
MRPC Probe - Axial Extent



APPENDIX D

VOLTAGE TO DEFECT PERCENT THROUGH WALL CORRELATION BY THE EPRI NDE CENTER

EPRI NDE CENTER

Electric Power Research Institute
Nondestructive Evaluation Center _________________ *Leadership in Technology Transfer*

December 6, 1993

Mr. Jeffery C. Brown
B&W Nuclear Service Company
Special Products & Integrated Services
155 Mill Ridge Road
Lynchburg, VA 24502

SUBJECT: P.O. 83-786323: Eddy Current Voltage-to-Volume Wall Loss Evaluation (13-19)

Dear Jeff:

Evaluation results of the subject work are summarized in this letter report. The main objective was to investigate the relation between eddy current signal amplitude and intergranular attack (IGA) volume wall loss. Our evaluation results were encouraging; a high degree of correlation between the eddy current signal amplitude and IGA wall loss was attained. Due to limited resources and time available, only the analyses of narrow-groove (510 M/ULC/HF/NG) and conventional (510 M/ULC/HF) bobbin-coil data were performed. No rotating pancake coil data was analyzed.

As indicated in my March 24, 1993 letter correspondence to P. Sherburne, no correlation between the eddy current phase angle and percent wall loss was noted for the identified IGA patches. This activity, therefore, involved evaluating the signal amplitude of IGA signal to known IGA wall losses. Specifically, the vertical amplitude, VMax, of IGA signal was measured and compared with metallurgically derived percent wall losses at frequencies of 600, 400, and 200 kHz. Initial attempts to correlate the ASME-based VMax amplitude to IGA wall loss was unsuccessful due mainly to larger flat-bottom hole signals of the ASME standard being compared to smaller amplitude IGA signals.

To overcome this problem, actual IGA data was used to establish the relevant VMax amplitude-to-percent wall loss curves at three different frequencies. This was accomplished by referring to the tabulated destructive analysis results of IGAs from four pulled tubes, e.g., tubes 52-51, 90-28, 97-91, and 106-32. Corresponding VMax amplitude information was obtained from both laboratory (narrow-groove bobbin coils) and field (conventional bobbin coils) eddy current data. Care was taken to select only those isolated, and not clustered, IGAs which were detectable by eddy current. Ten isolated signals were then used to establish the calibration curves using both first order and second order curve fits. Examples of established calibration curves from 600, 400, and 200 kHz narrow-groove bobbin-coil data are included as Figures A1-A3 in Attachment A. In the final analysis, more linear first order fit was selected over the second order fit to extend the calibration curve up to the 100% wall loss point. Figures A4-A6 show examples of calibration curves based just on the first order curve fit using the conventional bobbin coil data. For more accurate sizing, those calibration curves exhibiting lower, not higher, slopes are desirable. In general, the slope of the curve decreases with the higher operating frequency. This was especially true for the narrow-groove bobbin coils. With conventional bobbin coils, however, there were slight differences in the slope between the 600 and 400 kHz calibration curves (see Figures A4 and A5).

The next step was to estimate the IGA depths by using the established calibration curves. Derived estimates were then compared with the destructive analysis results. Attachment B shows the comparative analysis results of both the narrow-groove and conventional bobbin coils. Table B1 shows 10 specific IGA points used to establish the VMax calibration curves plus 24 additional test points based on the laboratory data (narrow-groove bobbin coils). Figures B1-B3 show comparison of destructive analysis results versus eddy current estimates for 600, 400, and 200 kHz. It should be noted that the 34 test points used in the linear regression analysis included the original 10 points used to establish the calibration curve. Best analysis results were obtained using the 600 kHz differential VMax amplitude curve. The following statistically derived values were obtained: correlation coefficient of 74%; RMS error of 8%; and slope of 0.83. The overall accuracy of sizing increases with higher correlation coefficient and slope values accompanied by the smaller RMS error value. These values represent significant improvements over the phase angle analysis results, which yielded correlation coefficient of 25%, RMS error of 27%, and slope of 0.65.

To determine if comparable analysis results can be obtained from the field data, similar comparisons were made using the same data set as shown in Table B2. Comparative results of 600, 400, and 200 kHz data are graphically illustrated as Figures B4-B6, respectively. Although the analysis results of field data were slightly degraded, especially the slope value, they still represented improvements over the phase angle analysis results. Of the three frequency analysis results, the 600 kHz results showed slightly better performance over others as shown below.

	Correlation Coefficient	RMS Error	Slope
600 kHz VMax	73%	7%	0.69
400 kHz VMax	74%	7%	0.56
200 kHz VMax	70%	7%	0.56

It should be noted that no IGA patches of less than 30% penetration depths will be reliably detected nor sized based on the currently established calibration curves from either laboratory or field data (see calibration curves A1-A6). This basically defines the current limitation of the bobbin coil technology.

Although useful, the established calibration curves can not be used in their original forms by either DDA-4 or Eddynet analysis software. Consequently, an attempt was made to transpose the IGA curve using the readily available ASME standard readings. This attempt was made using the 400 kHz differential field data. Initially, two ASME standard readings, 100% and 40% VMax readings, were used to establish a linear calibration curve. This line was then rotated and translated to mimic the original IGA curve. These two ASME points, however, corresponded only to higher percent wall losses in the IGA curve, e.g., 99% and 72%. Thus, to complete the lower end of the calibration curve, 0 volt reading was also used, which for the 400 kHz data corresponded to 32%. The above steps are tabulated and graphically shown as Table C1 and Figure C1 in Attachment C. Figure C2 shows an example of transposed IGA curve based on the derived percent wall loss points corresponding to various ASME VMax readings.

Since calibration runs produce slightly different voltage readings, depending on the probe and ASME flaw orientations, any changes in the percent wall losses due to different VMax readings were investigated. From the four field calibration runs, the following highest and lowest VMax readings and the corresponding percent wall losses were compared with the original IGA wall losses.

ASME Hole	Min VMax Volts/ Forced Percent	Max VMax Volts/ Forced Percent	Actual IGA % Min/Max
100	3.22/99	3.38/99	96/99
40	2.00/74	2.11/73	72/74
20	2.44/83	2.77/87	81/87
0	0/32	0/30	32/32

Deviations in percent wall losses were minor as shown in Figures C3 and C4 Consequently, any VMax readings in the smallest to largest voltage range should provide comparable analysis results as in the original IGA calibration curves. This amplitude curve can be saved as one of mixed channels. It should be noted that these readings are good for the specific probe type and the extension cable length used to acquire the field data. Any probe or extension cable changes may necessitate recalculation of the forced percentage points.

In summary, by using the actual IGA data points, it was possible to correlate the VMax amplitude signals to IGA depths. In addition, the transposed IGA curves, established from the ASME readings, can easily be established as one of the analysis curves for evaluating IGA patches.

If you have any questions or require additional information, please feel free to contact us.

Sincerely,

Kenji Krzywosz
Manager, Heat Exchanger & Electromagnetic NDE
EPRI NDE Center

KK:mph

Attachments

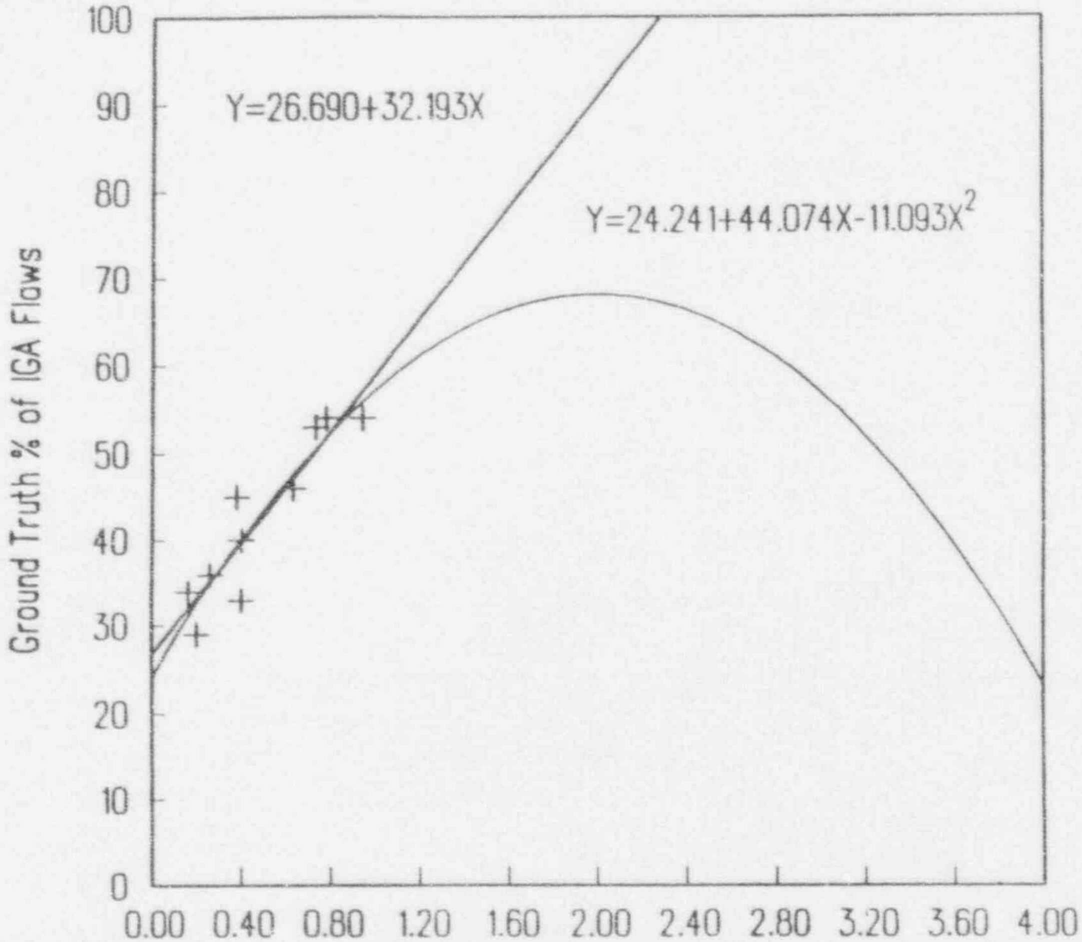
cc: S. Overstreet, B&W
R. Thompson, Crystal River
J. Lance, EPRI
R. Stone
F. Ammirato
S. Hastings
D. Spake
G. Henry

ATTACHMENT A

FIGURE A1

CR-3 IGA AMPLITUDE VS. VOLUME SIZING REVIEW

GROUND TRUTH % VS. AMPLITUDE (VOLTS)



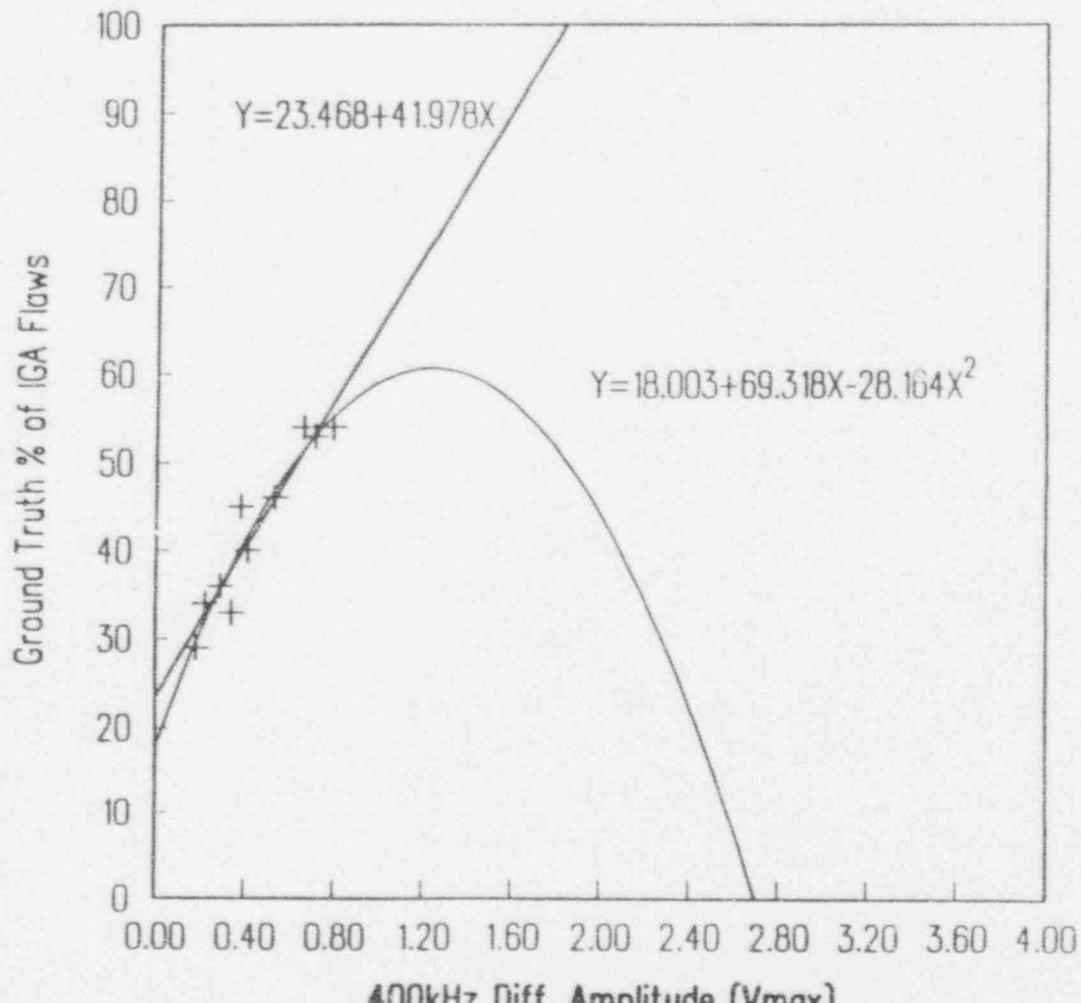
600kHz Diff. Amplitude (Vmax)

Curve based on 10 seleted data points.

FIGURE A2

CR-3 IGA AMPLITUDE VS. VOLUME SIZING REVIEW

GROUND TRUTH % VS. AMPLITUDE (VOLTS)

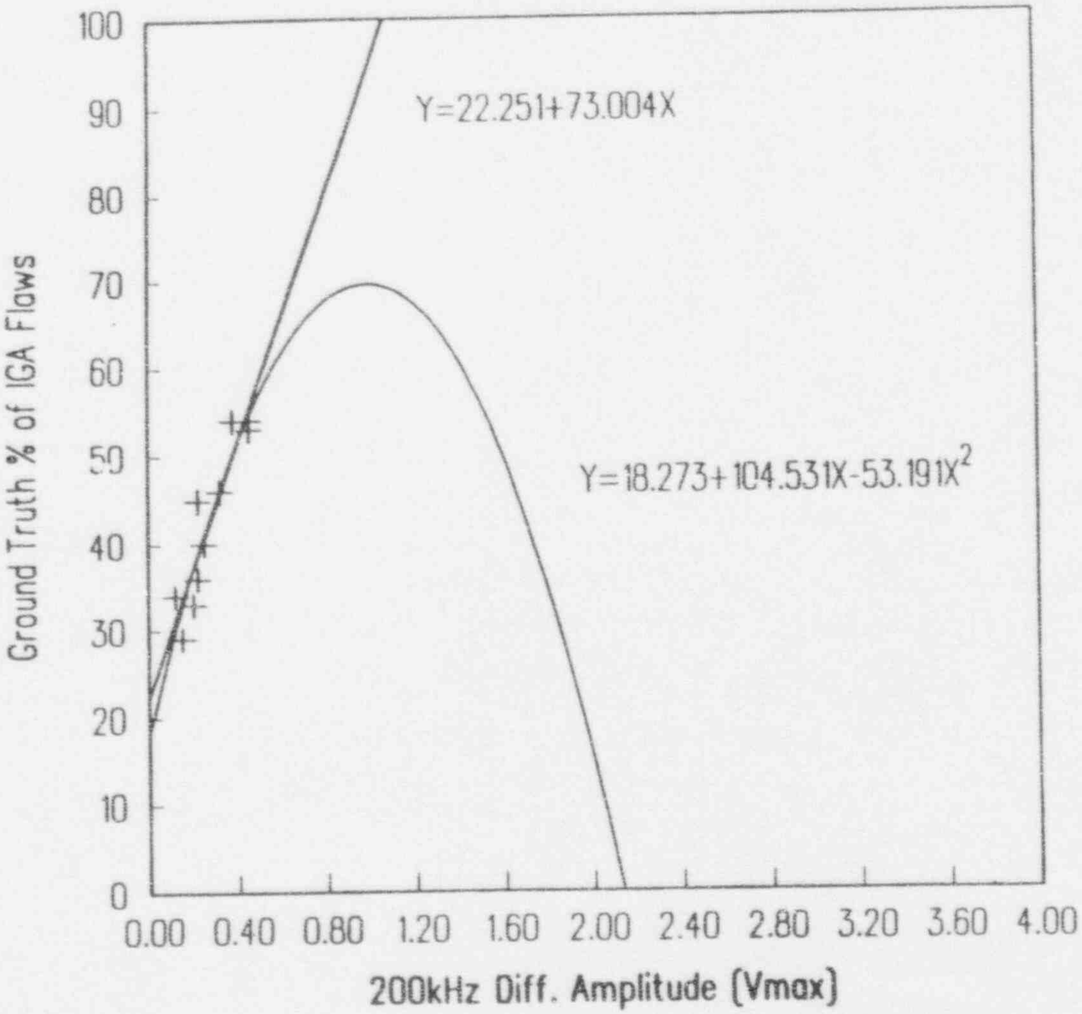


Curve based on 10 seleted data points.

FIGURE A3

CR-3 IGA AMPLITUDE VS. VOLUME SIZING REVIEW

GROUND TRUTH % VS. AMPLITUDE (VOLTS)

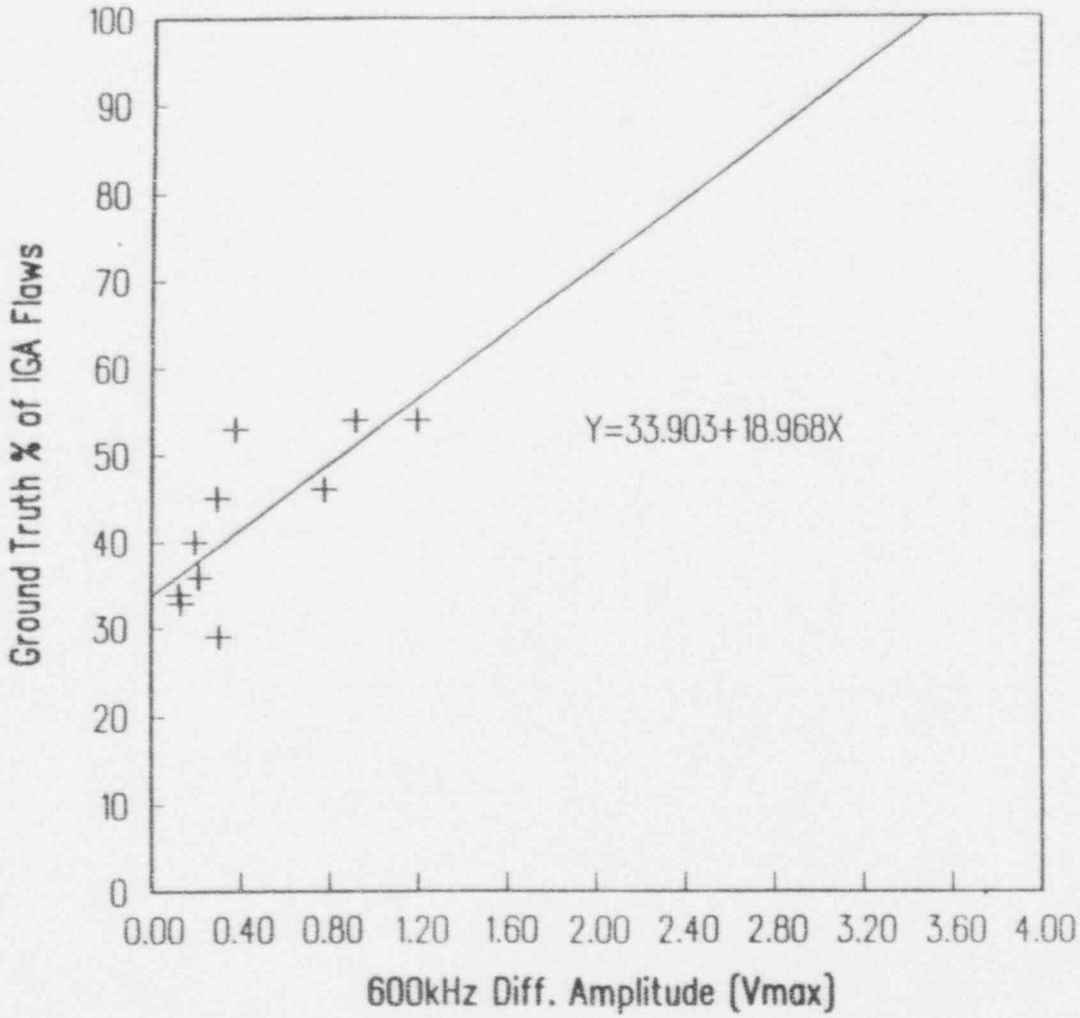


Curve based on 10 seleted data points.

FIGURE A4

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

GROUND TRUTH % VS. AMPLITUDE (VOLTS)

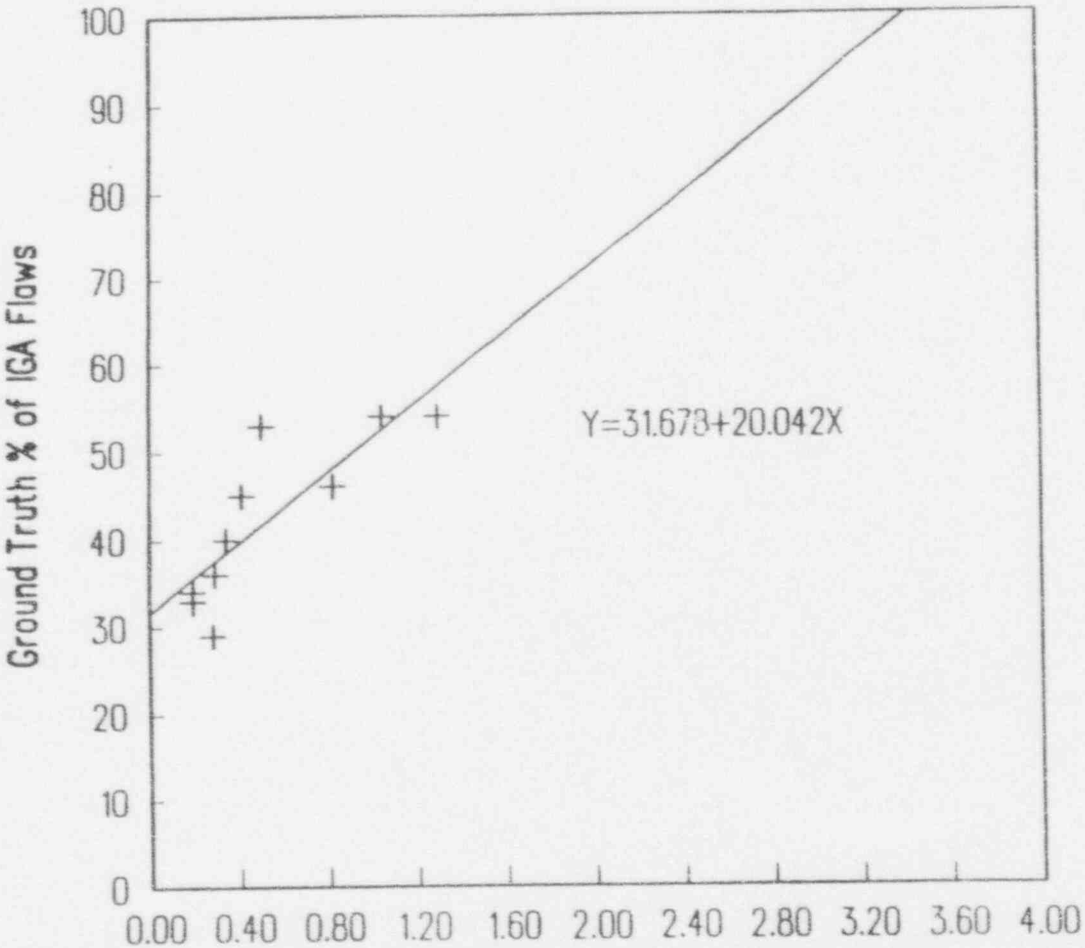


Curve based on 10 seleted data points.

FIGURE A5

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

GROUND TRUTH % VS. AMPLITUDE (VOLTS)



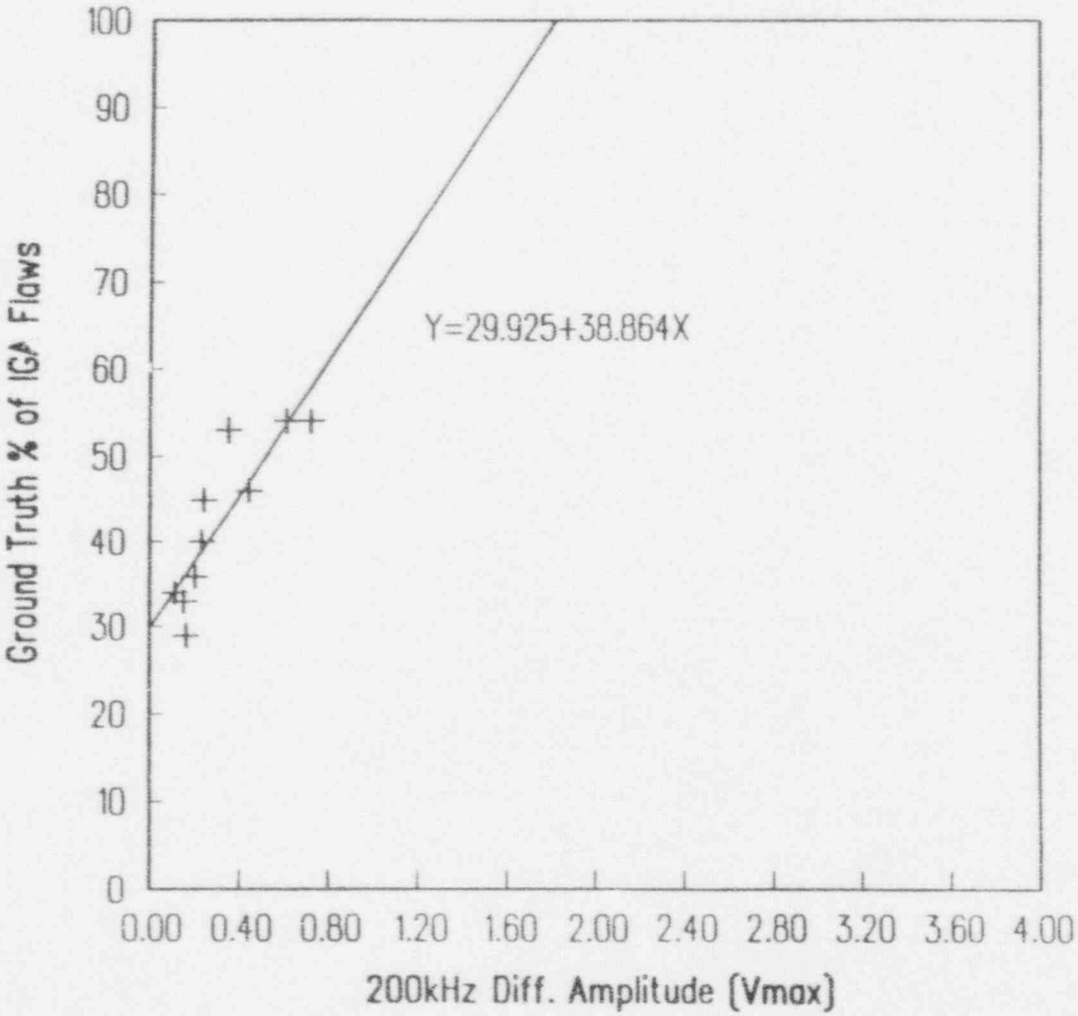
400kHz Diff. Amplitude (Vmax)

Curve based on 10 seleted data points.

FIGURE A6

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

GROUND TRUTH % VS. AMPLITUDE (VOLTS)



Curve based on 10 seleted data points.

ATTACHMENT B

<u>*CR-3 IGA ANALYSIS REVIEW*</u>

1st Order Curve Fit

(Includes 10 selected data points from laboratory data with a voltage of > zero.)

TABLE B1

		LOCATION	GROUND	600kHz DIFF		400kHz DIFF		200kHz DIFF	
TUBE	FLAW(S)	LTSF +	TRUTH%	VMAX	EST. %	VMAX	EST. %	VMAX	EST. %
52-51-2	D	+6.50	34	0.41	40	0.44	42	0.22	38
	F**	+8.90	53	0.73	50	0.71	53	0.45	55
	G**	+9.16	34	0.16	32	0.22	33	0.12	31
	I2/I1	+10.00	42	0.63	47	0.63	50	0.40	51
	K2/K1	+11.00	45	0.28	36	0.29	36	0.16	35
	N2/N1	+12.40	30	0.26	35	0.22	33	0.12	31
	P	+13.10	33	0.18	32	0.15	30	0.09	29
	S**	+14.70	33	0.40	40	0.34	38	0.20	37
90-28-2	AD1/AD2	+16.10	37	0.22	34	0.28	35	0.16	34
	AB	+15.50	30	0.16	32	0.18	31	0.13	32
	X2/X1	+14.60	43	0.61	46	0.59	48	0.33	46
	V2/V1	+14.00	48	0.90	56	0.82	58	0.52	60
	Q**	+12.30	45	0.38	39	0.38	39	0.22	38
	O/N/M	+11.50	43	0.65	48	0.54	46	0.30	44
	I/H/G	+10.20	49	0.96	58	0.81	57	0.42	53
	E	+7.80	50	1.40	72	1.27	77	0.66	70
	C/B	+6.10	41	0.98	58	0.90	61	0.50	59
97-91-2	W**	+14.10	54	0.94	57	0.79	57	0.46	56
	U/T/S	+11.50	46	0.62	47	0.63	50	0.45	55
	P**	+8.55	46	0.63	47	0.53	46	0.32	46
	O**	+8.30	54	0.78	52	0.66	51	0.38	50
	K**	+6.60	29	0.20	33	0.18	31	0.15	33
106-32-2	X2/Y/X1	+6.40	28	0.48	42	0.53	46	0.36	49
	Z/AA	+7.00	34	0.20	33	0.22	33	0.13	32
	AC1/AB	+7.40	18	0.11	30	0.25	34	0.22	38
	AE/AD/AC2	+7.70	24	0.26	35	0.18	31	0.15	33
	AG2/AH	+8.80	35	0.28	36	0.33	37	0.20	37
	AJ	+9.60	38	0.24	34	0.22	33	0.17	35
	AK**	+9.90	40	0.40	40	0.41	41	0.25	41
	AP/AO	+11.20	27	0.48	42	0.46	43	0.29	43
	AQ2/AQ1	+11.70	35	0.30	36	0.34	38	0.22	38
	AT/AU/AV	+13.20	34	0.38	39	0.38	39	0.22	38
	AX	+14.30	32	0.17	32	0.21	32	0.16	34
	AY**	+14.60	36	0.26	35	0.29	36	0.22	38
109-30-2		*+13.45	No Met Work	0.26	35	0.32	37	0.22	38
		*+11.03	50	0.65	48	0.71	53	0.45	55
		*+9.81	40	0.28	36	0.25	34	0.16	34
		*+9.21	No Met Work	0.29	36	0.33	37	0.28	43
		*+8.36	No Met Work	0.20	33	0.18	31	0.15	33
		*+6.41	No Met Work	0.22	34	0.20	32	0.15	33
41-44-2		*+21.00	No Met Work	0.77	51	0.69	52	0.44	54
		*+18.86	No Met Work	0.46	41	0.41	41	0.32	46
		*+17.39	No Met Work	0.73	50	0.67	52	0.44	54
		*+16.33	No Met Work	0.25	35	0.20	32	0.09	29
		*+14.64	No Met Work	0.26	35	0.29	36	0.18	35
		*+12.77	No Met Work	0.59	46	0.54	46	0.37	49
		*+11.44	No Met Work	0.40	40	0.41	41	0.29	43
		*+10.93	No Met Work	0.28	36	0.32	37	0.16	34
		*+10.50	No Met Work	0.44	41	0.40	40	0.25	41

* indicates that the location is measured from the inspection end of the lab pull.

FIGURE B1

CR-3 IGA AMPLITUDE ANALYSIS/NARROW GROOVE LAB DATA

600kHz Differential Amplitude (Vmax)

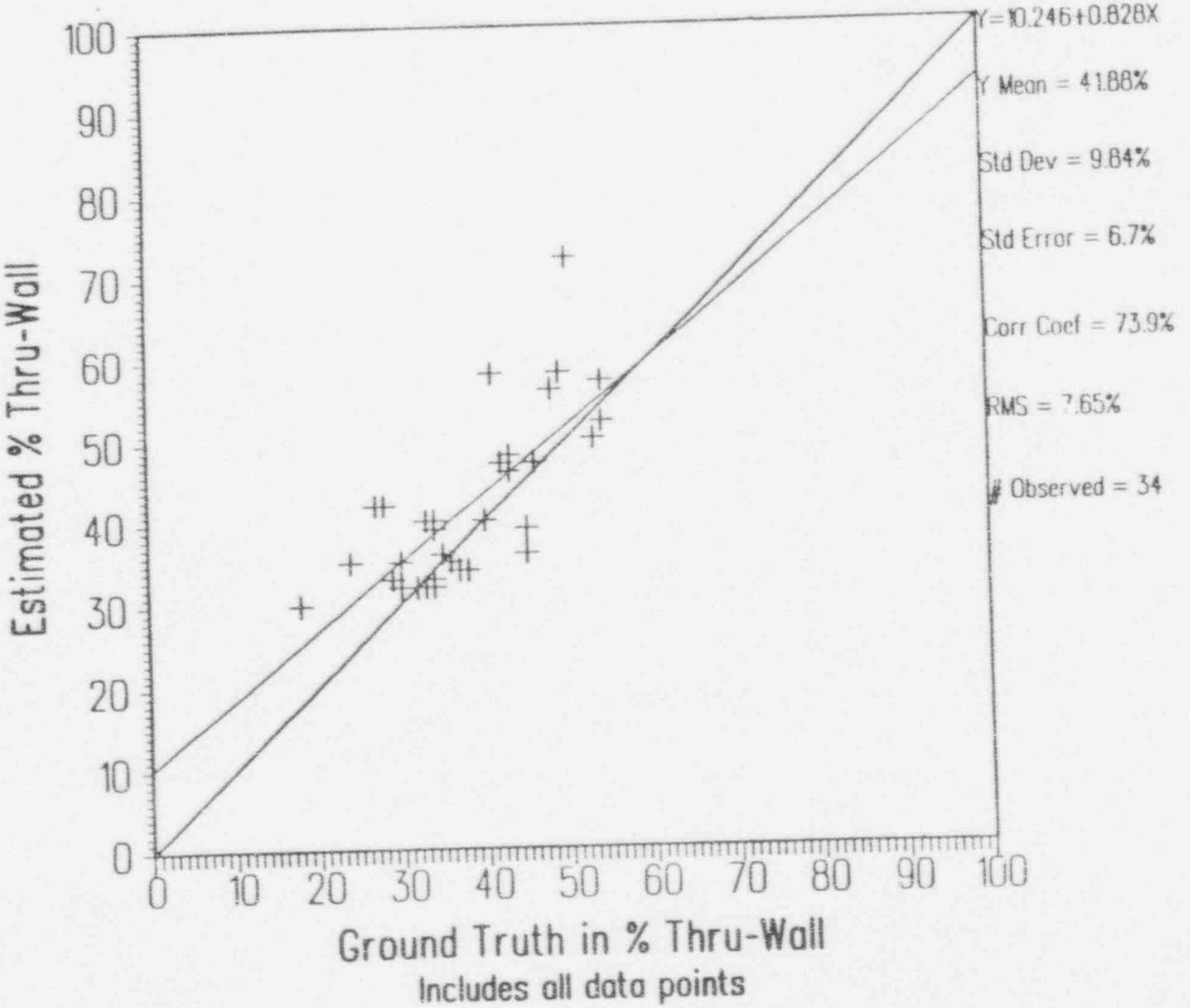


FIGURE B2

CR-3 IGA AMPLITUDE ANALYSIS/NARROW GROOVE LAB DATA

400kHz Differential Amplitude (Vmax)

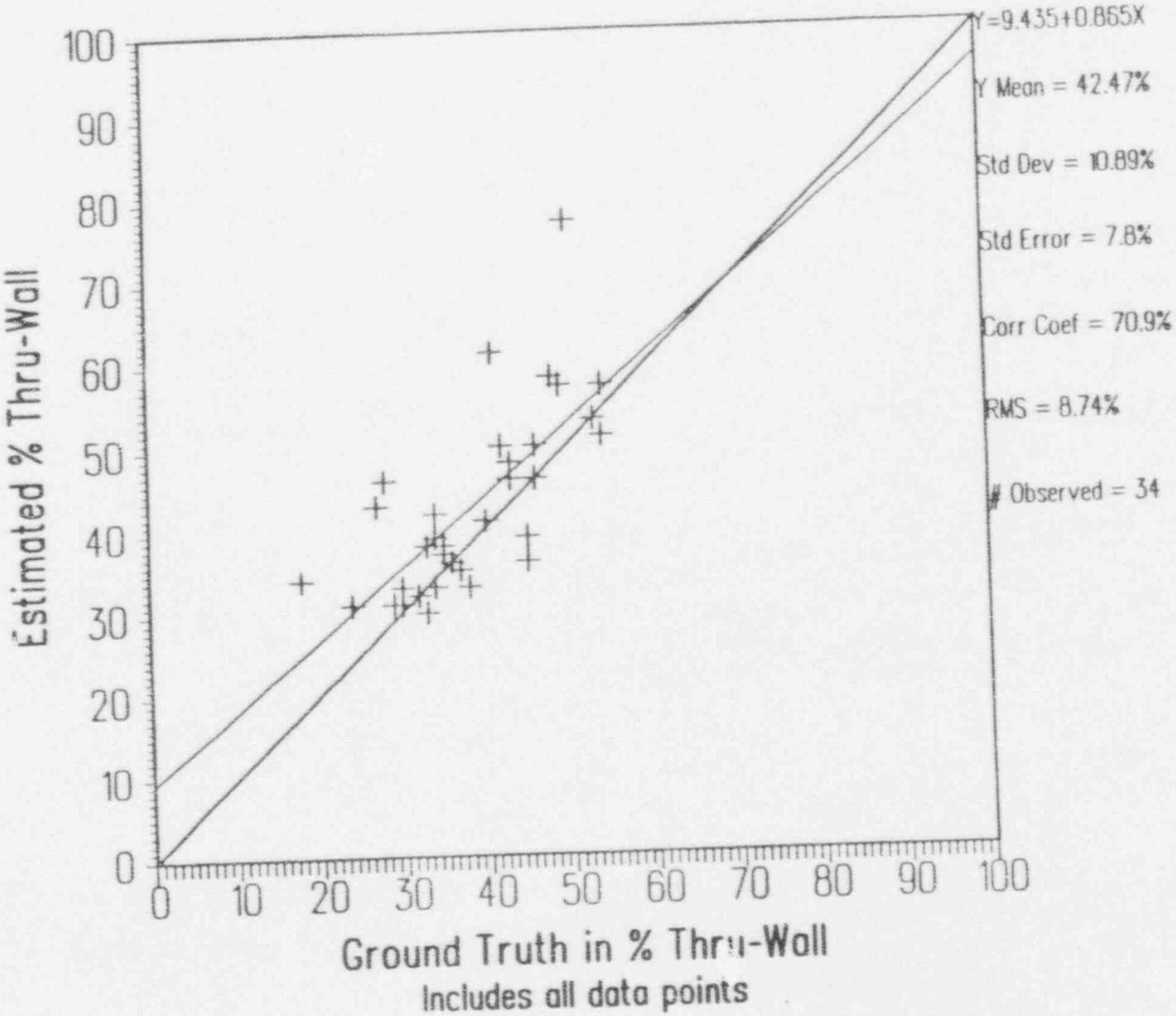
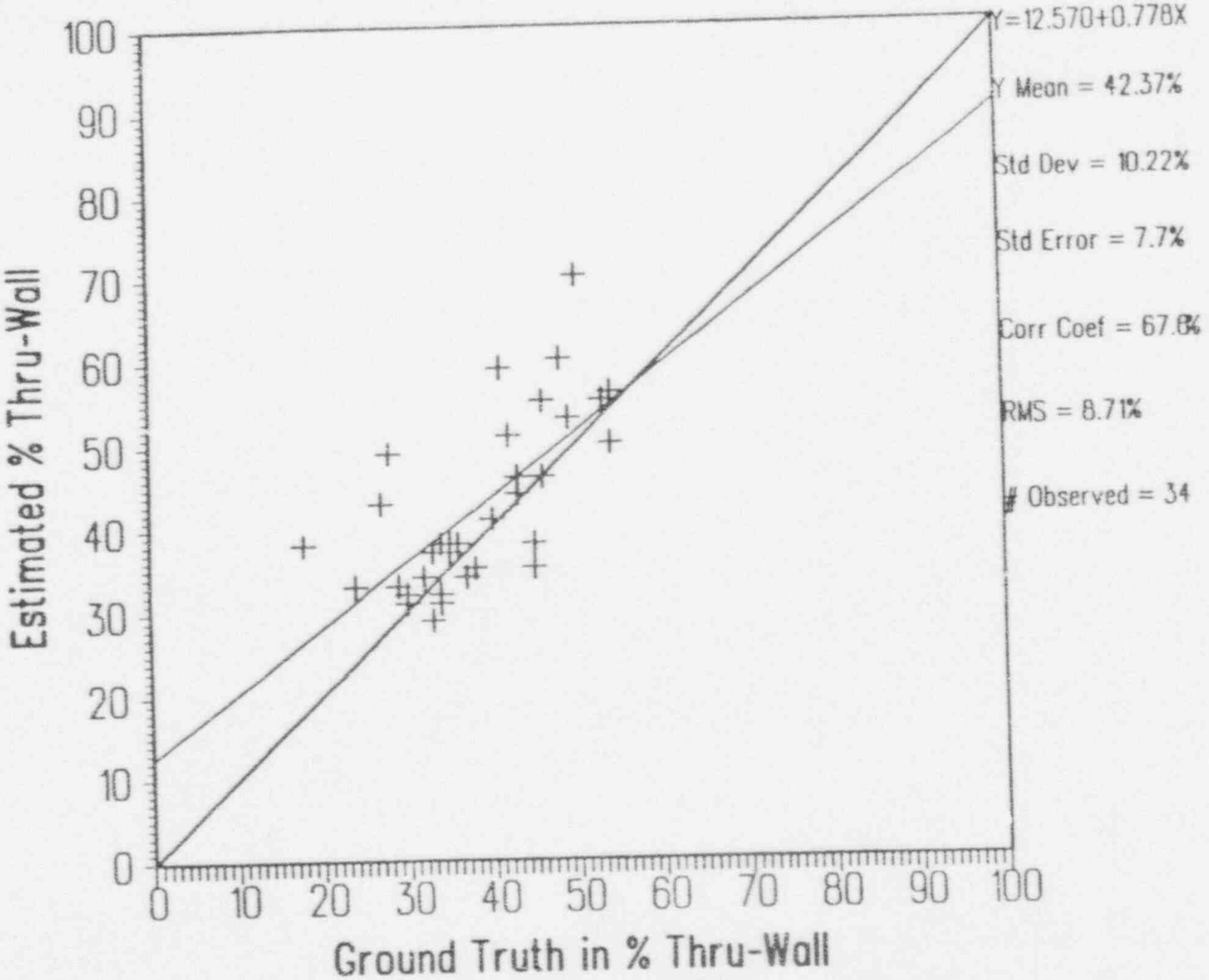


FIGURE B3

CR-3 IGA AMPLITUDE ANALYSIS/NARROW GROOVE LAB DATA

200kHz Differential Amplitude (Vmax)



Includes all data points

CR-3 IGA ANALYSIS REVIEW

1st Order Curve Fit

(Includes 10 selected data points from original field data with a voltage of > zero.)

TABLE B2

		LOCATION	GROUND	600kHz DIFF		400kHz DIFF		200kHz DIFF	
TUBE	FLAW(S)	LTSF +	TRUTH%	VMAX	EST. %	VMAX	EST. %	VMAX	EST. %
52-51-2	D	+6.50	34	0.31	40	0.38	39	0.22	38
	F**	+8.90	53	0.37	41	0.50	42	0.35	44
	G**	+9.16	34	0.12	36	0.19	35	0.11	34
	I2/I1	+10.00	42	0.30	40	0.47	41	0.31	42
	K2/K1	+11.00	45	0.31	40	0.31	38	0.18	37
	N2/N1	+12.40	30	0.16	37	0.21	36	0.10	34
	P	+13.10	33	0.12	36	0.13	34	0.07	33
	S**	+14.70	33	0.13	36	0.19	35	0.15	36
92-28-2	AD1/AD2	+16.10	37	0.20	38	0.25	37	0.18	37
	AB	+15.50	30	0.08	35	0.15	35	0.15	36
	X2/X1	+14.60	43	0.40	41	0.57	43	0.32	42
	V2/V1	+14.00	48	0.74	48	0.91	50	0.52	50
	Q**	+12.30	45	0.29	39	0.41	40	0.24	39
	O/N/M	+11.50	43	0.44	42	0.47	41	0.23	39
	I/H/G	+10.20	49	0.66	46	0.79	48	0.42	46
	E	+7.80	50	1.09	55	1.31	58	0.70	57
	C/B	+6.10	41	0.75	48	0.87	49	0.53	51
97-91-2	W**	+14.10	54	0.91	51	1.04	53	0.61	54
	U/T/S	+11.50	46	0.78	49	0.91	50	0.66	56
	P**	+8.55	46	0.77	49	0.82	48	0.44	47
	O**	+8.30	54	1.19	56	1.29	58	0.72	58
	K**	+6.60	29	0.30	40	0.28	37	0.16	36
106-32-2	X2/Y/X1	+6.40	28	0.45	42	0.56	43	0.36	44
	Z/AA	+7.00	34	0.08	35	0.23	36	0.12	35
	AC1/AB	+7.40	18	0.14	37	0.30	38	0.26	40
	AE/AD/AC2	+7.70	24	0.13	36	0.17	35	0.12	35
	AG2/AH	+8.80	35	0.23	38	0.26	37	0.17	37
	AJ	+9.60	38	0.11	36	0.21	36	0.15	36
	AK**	+9.90	40	0.19	38	0.34	38	0.23	39
	AP/AO	+11.20	27	0.21	38	0.36	39	0.24	39
	AQ2/AQ1	+11.70	35	0.18	37	0.34	38	0.24	39
	AT/AU/AV	+13.20	34	0.17	37	0.19	35	0.11	34
	AX	+14.30	32	0.26	39	0.26	37	0.17	37
	AY**	+14.60	36	0.21	38	0.29	37	0.20	38
109-30-2		+6.17	No Met Work	0.24	38	0.33	38	0.24	39
		+8.50	50	0.51	44	0.68	45	0.41	46
		+9.72	40	0.20	38	0.29	37	0.17	37
		+10.32	No Met Work	0.28	39	[illegible]	39	0.24	39
		+11.17	No Met Work	0.13	36	0.16	35	0.11	34
		+13.06	No Met Work	0.15	37	0.21	36	0.15	36
41-44-2		+15.99	No Met Work	0.42	42	0.50	42	0.30	42
		+13.81	No Met Work	0.25	39	0.30	38	0.22	38
		+12.14	No Met Work	0.40	41	0.48	41	0.29	41
		+11.01	No Met Work	0.08	35	0.08	33	0.08	33
		+9.63	No Met Work	0.18	37	0.19	35	0.13	35
		+7.35	No Met Work	0.49	43	0.57	43	0.33	43
		+6.11	No Met Work	0.23	38	0.31	38	0.23	39
		+5.63	No Met Work	0.10	36	0.16	35	0.10	34
		+5.23	No Met Work	0.14	37	0.23	36	0.18	37

** indicates flaws used as calibration points.

FIGURE B4

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

600kHz Differential Amplitude (Vmax)

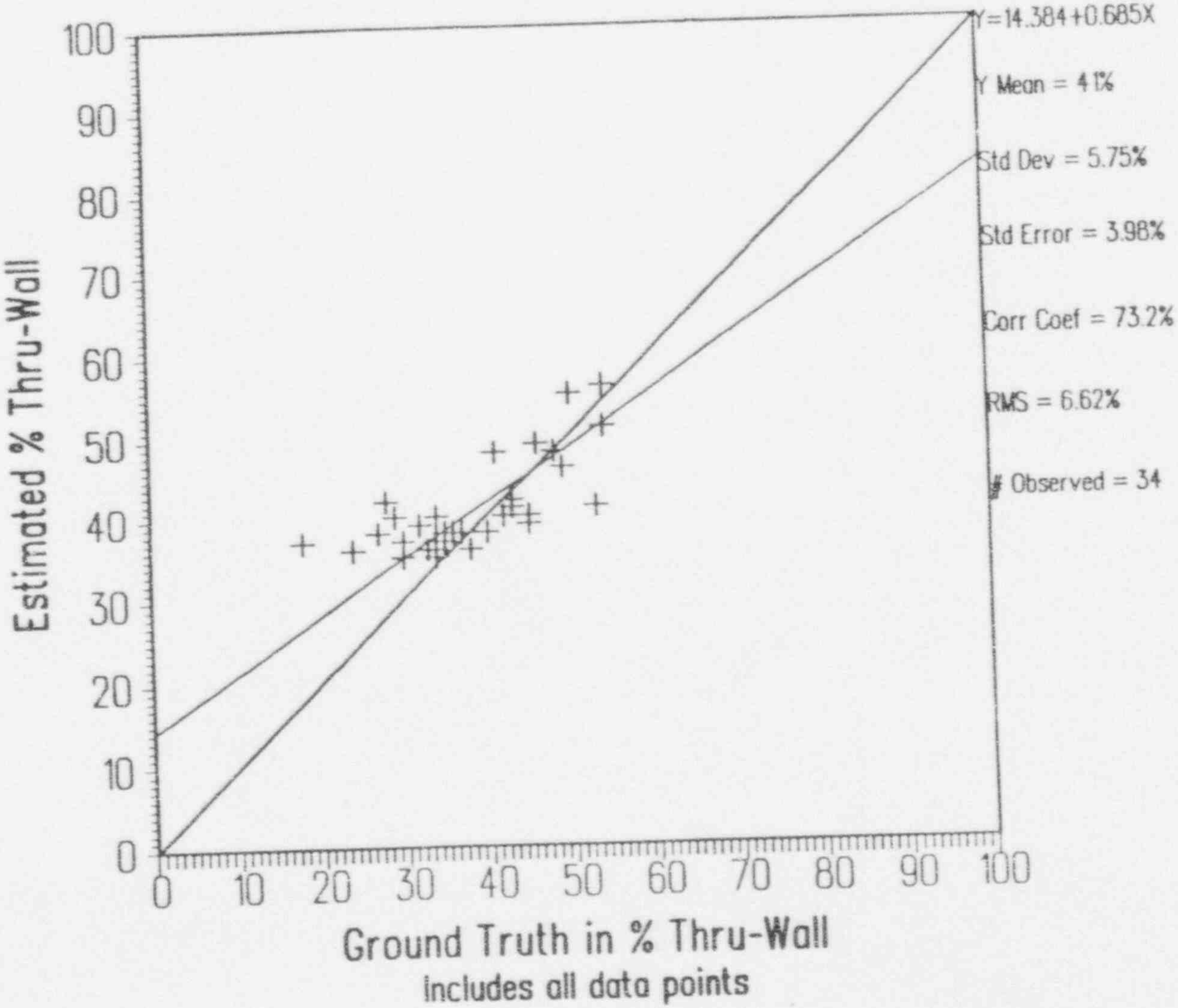
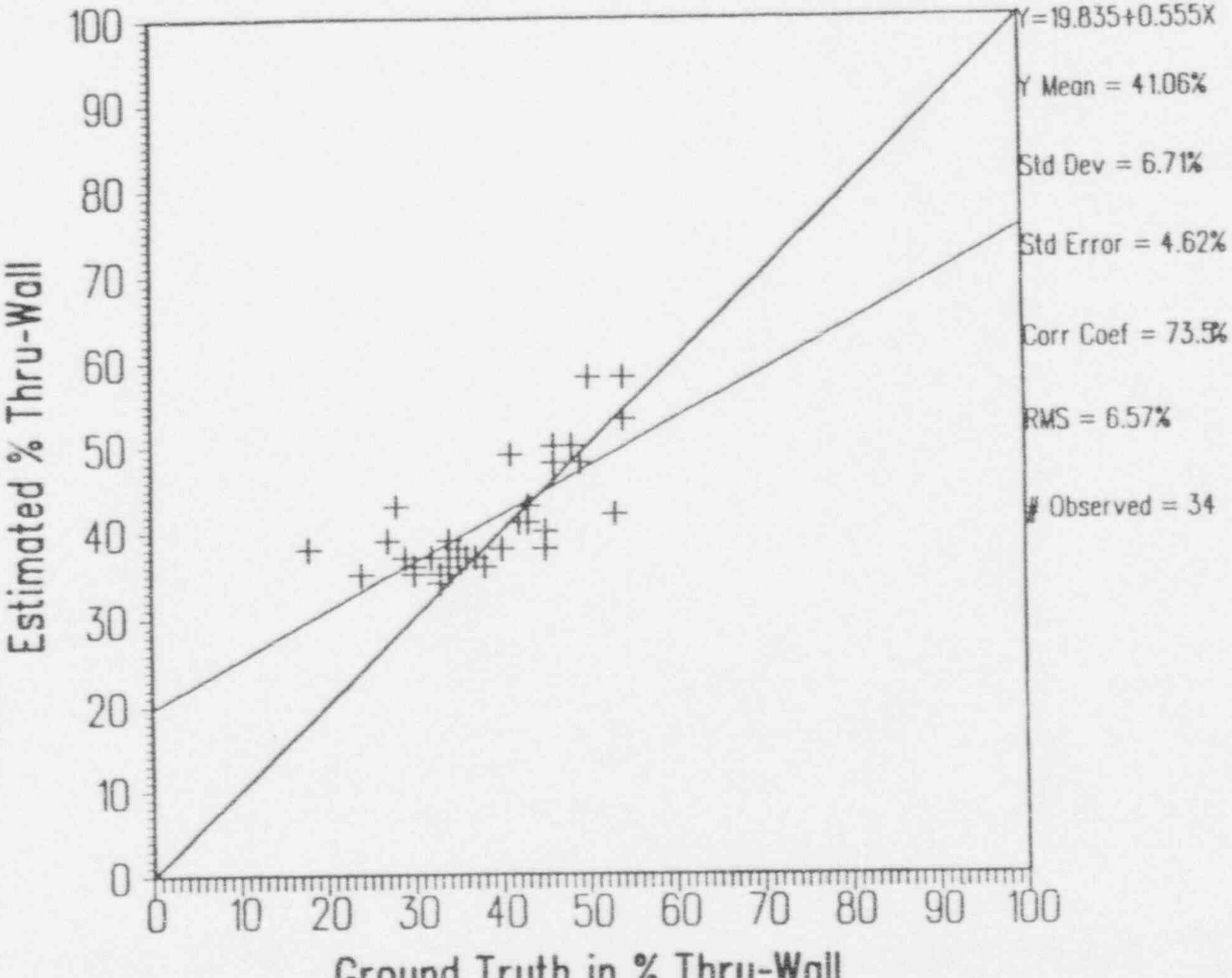


FIGURE B5

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

400kHz Differential Amplitude (Vmax)

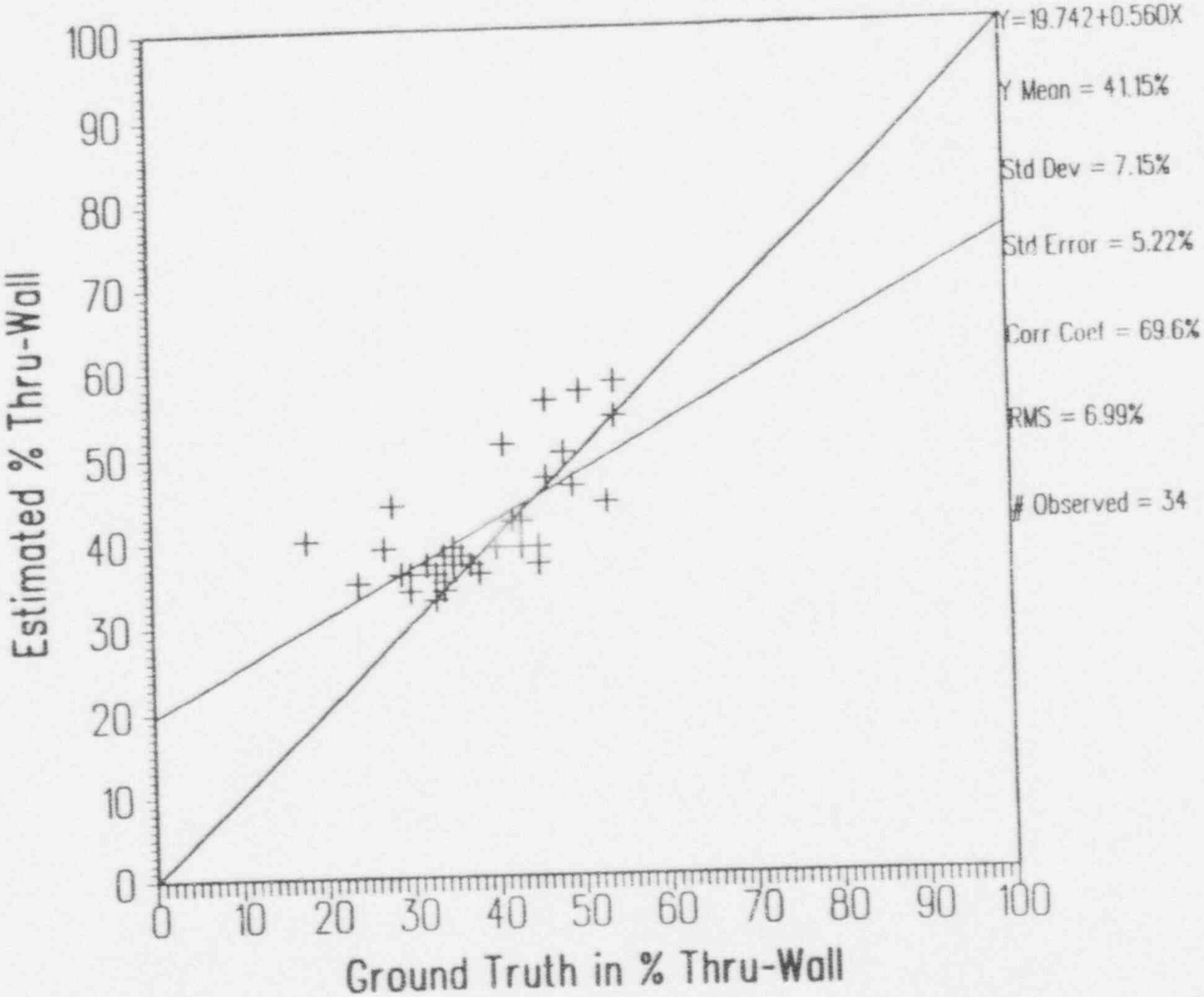


Includes all data points

FIGURE B6

CR-3 IGA AMPLITUDE ANALYSIS/FIELD DATA

200kHz Differential Amplitude (Vmax)



Includes all data points

ATTACHMENT C

TABLE C1

CALIBRATION TRANS/ROTATION MATRIX
400 Khz DIFFERENTIAL VERT MAX

100% ASME VOLTAGE READING / %Thru-Wall

ROTATION MATRIX

0.999621723	0.027502920
0.027502920	0.999621723

DATA		ROTATED DATA
3.37	V	6.119017
100	%	99.869487

40% ASME VOLTAGE READING / %Thru-Wall

ROTATION MATRIX

0.999621723	0.027502920
-0.027502920	0.999621723

DATA		ROTATED DATA
2.03	V	3.129349
40	%	39.929038

TRANSLATION OF VOLTAGE READINGS

TRANSLATION MATRIX

2.714150	0

3.37
2.03

TRANSLATED DATA

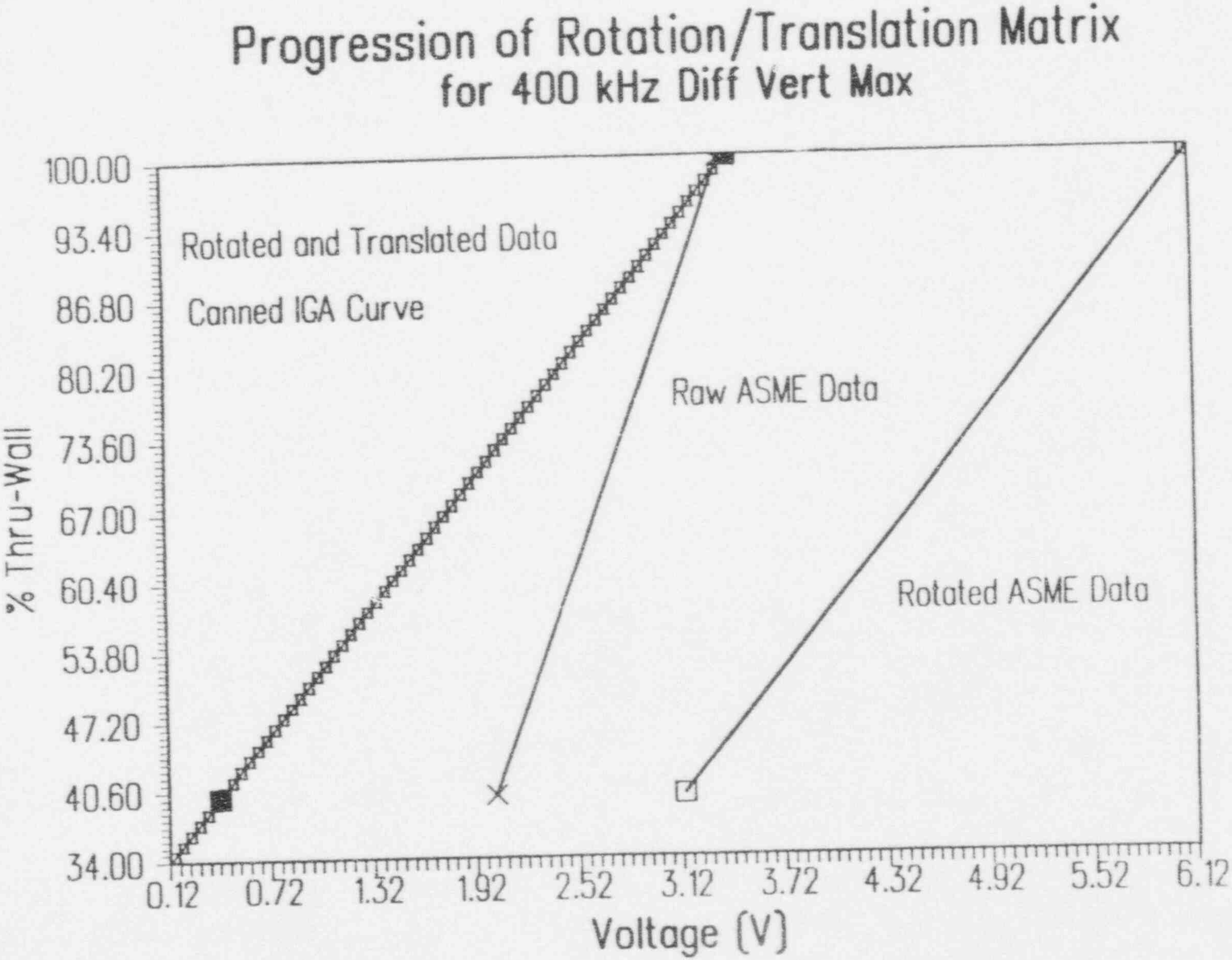
Volts	%THRU WALL
3.404867207	100%
0.415198898	40%

LINEAR INTERPOLATION OF ROTATED AND TRANSLATED DATA

GT %THRU_WALL ASME FLAW	VOLTS	ASME Forced %THRU_WALL	ACTUAL IGA CURVE FROM PULLED TUBES	%DIFFERENCE
100	3.37	99.3002 %	99.2128	0.044050500
40	2.03	72.4076 %	72.3592	0.033454203
20	2.60	83.8470 %	83.7820	0.038792024
0	0.00	31.6673 %	31.6780	0.016851801

NOTE: FORCE THE ASME FLAWS IN BLACK TO THE CORRESPONDING %THRU-WALL IN BLACK TO GENERATE THE IGA CALIBRATION CURVE BASED ON PULLED TUBE DATA

FIGURE C1



Progression of Rotation/Translation Matrix
for 400 kHz Diff Vert Max
100.00
93.40
86.80
80.20
73.60
67.00
60.40
53.80
47.20
40.60
34.00
% Thru-Wall
Rotated and Translated Data
Canned IGA Curve
Raw ASME Data
Rotated ASME Data
0.12
0.72
1.32
1.92
2.52
3.12
3.72
4.32
4.92
5.52
6.12
Voltage (V)

FIGURE C2

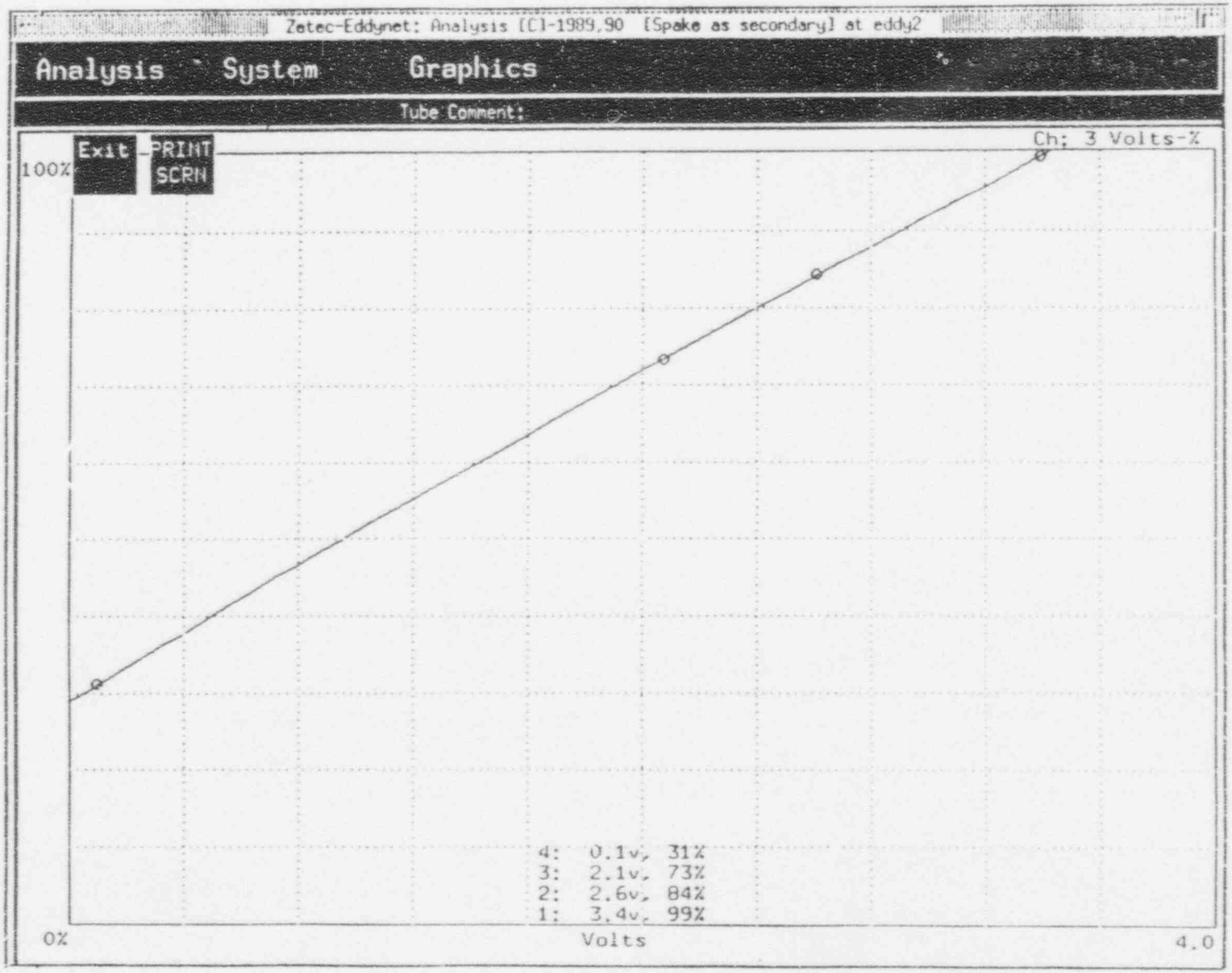
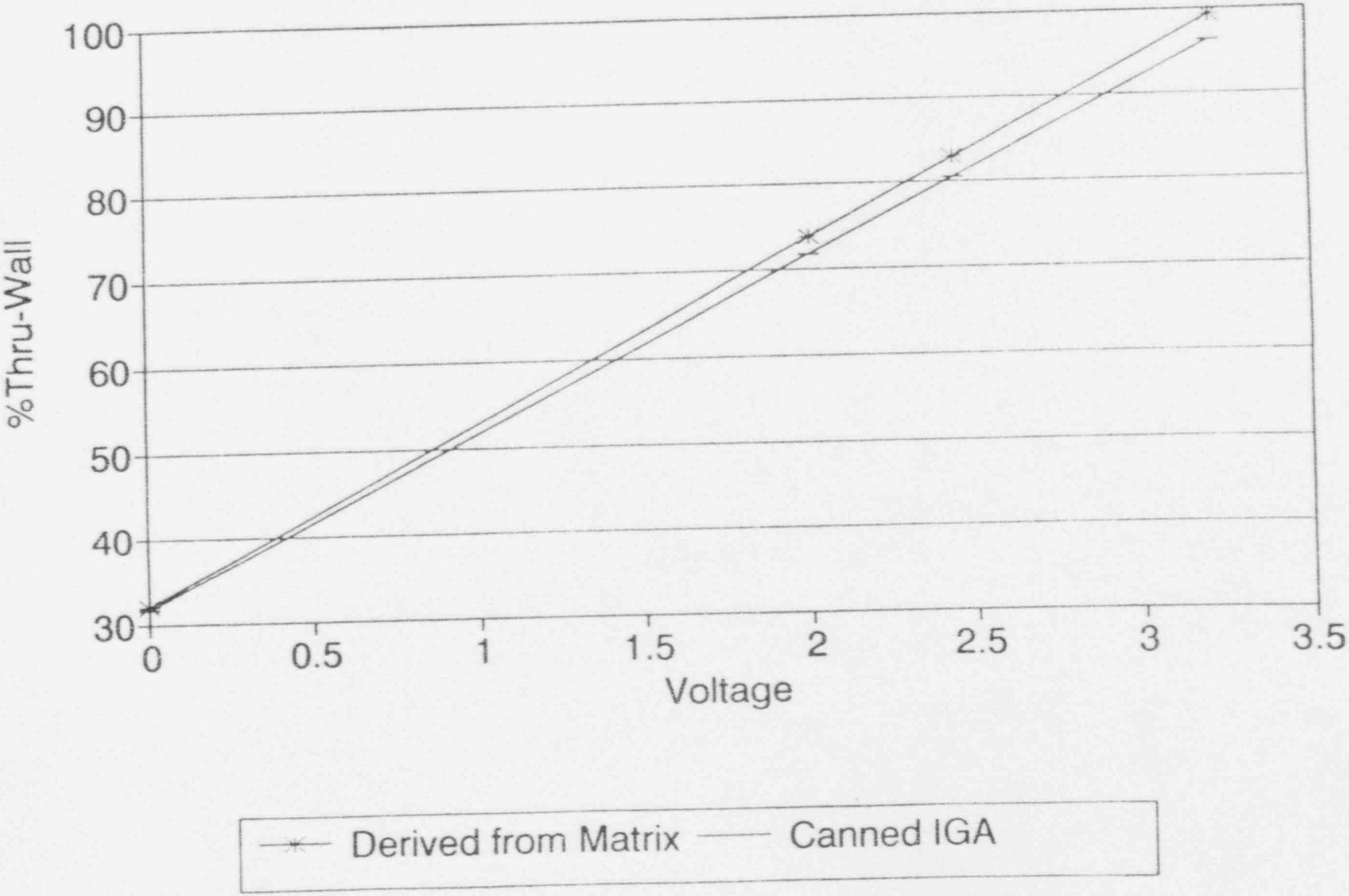

Zetec-Eddynet: Analysis [C]-1989,90 [Spake as secondary] at eddy2
Analysis
System
Graphics
Tube Comment:
Exit
PRINT SCRN
Ch: 3 Volts-%
100%
4: 0.1v, 31%
3: 2.1v, 73%
2: 2.6v, 84%
1: 3.4v, 99%
0%
Volts
4.0

FIGURE C3

Plot of Canned IGA to TRANS/ROTATED

ASME Field Data for Smallest Voltage's



APPENDIX E

MPR MINIIMUM LIGAMENT CALCULATiON

Florida Power CORPORATION

INTEROFFICE CORRESPONDENCE

Nuclear Engineering	NA2G	240-3512
OFFICE	MAC	PHONE

SUBJECT: Crystal River Unit No. 3
Quality Document Transmittal - Analysis/Calculations
File: CALC

TO: Records Management - NR2A

The following analysis/calculation package is submitted as the QA Record copy:

DOCNO (FPC DOCUMENT IDENTIFICATION NUMBER)	REV	SYSTEM(S)	TOTAL PAGES TRANSMITTED
M 94-0025	0	RC/MS	10

TITLE
STEAM GENERATOR TUBE MINIMUM LIGAMENT CALCULATION

KWDS (IDENTIFY KEYWORDS FOR LATER RETRIEVAL)
OTSG, TUBES, STEAM GENERATOR

DXREF (REFERENCES OR FILES - LIST PRIMARY FILE FIRST)

VEND (VENDOR NAME)	VENDOR DOCUMENT NUMBER (DXREF)	SUPERSEDED DOCUMENTS (DXREF)
MPR Associates, Inc.	Part of N/A 102-071-HWM3	N/A

TAG

RCSG-1A		
RCSG-1A		

PART NO.

COMMENTS (USAGE RESTRICTIONS, PROPRIETARY, ETC.)
See attached continuation page.

NOTE:
Use Tag number only for valid tag numbers (i.e., RCV-8, SWV-34, DCH-99), otherwise; use Part number field (i.e., CSC14599, AC1459). If more space is required, write "See Attachment" and list on separate sheet.

DESIGN ENGINEER	DATE	VERIFICATION ENGINEER	DATE	SUPERVISOR, NUCLEAR ENG	DATE
Phyllis L Dixon	4/18/94	N/A		[signature] for AP	4-20-94

cc: MAR Office (If MAR Related) ☐ Yes ☒ No
MAR/Project File
Mgr., Nucl. Config. Mgt.
File (CALC) – FPES - "Original" w/attach
Mgr., Site Nucl. Eng. Serv. w/attach

Supervisor, Nuclear Document Control w/Plant Doc. Rev. Eval. and Analysis / Calc. Summary
Plant Document Review Required ☒ Yes ☐ No
A/E ______________ ☐ Yes ☒ No
(If Yes, Transmit w/attach)

RET: Life of Plant RESP: Nuclear Engineering 900 026

Rev 3/93

Florida Power
CORPORATION

ANALYSIS / CALCULATION
Continuation Sheet
Crystal River Unit 3

REI/MAR NUMBER
M94-0025

COMMENTS (Continued from coversheet)

MPR calculation 102-071-HWM3 determined the steam generator tube wall minimum ligament which must be present to prevent leakage under a differential pressure equal to the RCS normal operating pressure. For conservatism, NRC staff has requested that FPC look at the effect of using a higher differential pressure (2600 psid) on the minimum ligament required.

From the figure on page 5 of the calculation, it can be determined that the maximum degradation (%wall) corresonding to a burst pressure of 2600 psi would be approximately 88%. The remaining wall thickness would then be:

$$t_R = (1-0.88) * 0.034" = 0.00408"$$

The adjusted remaining wall thickness with the CR#3 actual material properties at operating temperature would be:

$$t_R + 0.00408" * (99.8 \text{ ksi}/92.9 \text{ ksi}) = 0.004383"$$

Which corresponds to a percent wall degradation of:

$$\text{Allowable \%wall loss} = 1 - (0.004383"/0.034") = 87.1\%$$

Therefore, increasing the pressure differential from RCS normal operating to 2600 psid decreases the allowable wall loss to prevent leakage from 91.5% to 87.1%.