P.O. BOX 529100 MIAMI, FL 33152

FLORIDA POWER & LIGHT COMPANY

February 27, 1981
L-81-88

Office of Nuclear Reactor Regulation
Attention: Mr. Steven A. Varga, Chief
Operating Reactors Branch #1
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Varga:

Re: Turkey Point Unit 4
Docket No. 50-251
Steam Generator Tube Wastage Information

Amendment 54 to the Turkey Point Unit 4 Facility Operating License authorized six months of operation subject to the submittal of confirmatory data regarding tube wastage. FPL received the specific items requested by the NRC on January 30, 1981.

The attached report provides the tube wastage predictions and other associated supplemental information requested by the Staff. The analysis, using conservative assumptions, confirms that the currently authorized 6 month operating period is conservatively bounded by the tube wastage predictions. In addition, with respect to tube wastage, the analysis supports a minimum operating period in excess of 14 equivalent full power months.

Very truly yours,

Robert E. Uhrig

Robert E. Uhrig
Vice President
Advanced Systems & Technology

REU/JEM/ras

Attachment

cc: J. P. O'Reilly, Region II
Harold F. Reis, Esquire

A001
S
1/1

8104060572

P

FLORIDA POWER AND LIGHT COMPANY

TURKEY POINT UNIT 4

SUPPLEMENTAL INFORMATION ON

S/G TUBE WALL THINNING

During the 11/80 outage, the steam generator tubes at Turkey Point Unit 4 were inspected as required by the stipulations in the plant operating license. The eddy current testing (ECT) indications showed some instances of apparent tube degradation above the top of the tubesheet. A review of the ECT tapes from the previous inspection showed that in the steam generator (B-cold leg) with the highest apparent tube degradation, 46 tubes with indications had been included in the previous inspection program. These 46 tubes with two successive estimates of tube wall degradation allow an estimated corrosion rate to be established. The rate calculated for these 46 tubes is 8.41% for 4.75 EFPM. This converts to 1.77% tube wall loss per EFPM. The detailed analysis of the steam generator inspection is attached in Appendix A.

The establishment of an estimate corrosion rate allows an operating interval to be determined. The present tube plugging criteria for Turkey Point Unit 4 require that tubes with ECT indications of 40% or greater shall be plugged. This means that the largest indication still in service is 39%. A 39% indication converts to 61% of the tube wall remaining.

The tubes in these steam generators are nominally 7/8 inch O.D. by .050 inch wall. The minimum tube wall that is required to maintain tube pressure integrity during a plant faulted condition event in the area near the top of the tubesheet is .013 inches. The detailed steam generator tube integrity evaluation supporting this minimum tube wall is contained in attached Appendix B. A remaining tube wall of .013 inches is 26% of the nominal tube wall. The difference between the minimum required tube wall (26%) and the minimum tube wall in service (61%) is the margin in tube wall thickness if tube wall degradation should continue; this margin is 35% of the tube wall. Using the estimated

corrosion rate of 1.77 per EFPM, an operating period of 19.88 EFPM can be justified. The quantification of ECT indications has some tolerance associated with the depth of the indication. The ECT tolerance applied by the NRC staff in the 35% to 40% range is $\pm$ 9%. For conservatism, it shall be assumed that the largest indication still in service is increased by 9%. Therefore, the 39% indication becomes 48% and the remaining wall is 52%. The difference between 52% and 26% is the conservative amount of tube wall margin if tube degradation should continue. The 26% tube wall margin combined with the estimated corrosion rate allows an operating period of 14.7 EFPM.

Considering the estimated operating intervals, a six month operating interval for the Turkey Point Unit 4 is considered to be a conservative operating interval.

APPENDIX A

EDDY CURRENT EVALUATION

TURKEY POINT UNIT 4, NOVEMBER, 1980

STEAM GENERATOR INSPECTION

I. INTRODUCTION

An evaluation of the eddy current data obtained in the November, 1980 steam generator inspection at Turkey Point Unit 4 was made in response to the NRC request for additional information relative to Amendment 54 authorizing operation of the unit for six equivalent months beginning January 13, 1981.

II. EXPANDED PROGRAM - NOVEMBER, 1980 INSPECTION

All pluggable thinning indications were found during the original eddy current testing program. The expanded program performed in accordance with Regulatory Guide 1.83 did not reveal any additional plugging indications.

III. EDDY CURRENT READINGS

Figures A-1 to A-6 show the distribution of eddy current indication ≥ 20% for each leg of the three steam generators. The preponderance of indications at low percentages, i.e. less than 40%, strongly suggests thinning as the nature of the tube degradation since detection of cracking by eddy current techniques is insensitive below about 40% wall penetration.

The eddy current readings for each of the pluggable thinning indications found in the November, 1980 inspection, including the coresponding readings obtained in April, 1979 and in May, 1980, as requested by the staff, as well as all previous indications recorded, are listed in Table A-1.

IV. AVERAGE INCREMENTAL THINNING CALCULATIONS, MAY, 1980 TO NOVEMBER, 1980

The average incremental wall thinning increase (in terms of percent of wall penetration) was calculated for each steam generator hot and cold leg, relative to the May, 1980 inspection for all tubes exhibiting thinning indications equal to or greater than 20% in December, 1980 and for which indications equal to or greater than 20% were observed in the May, 1980 inspection. The indications were observed at tube elevations from just above the top of the tubesheet to about 3 inches above the top of the tubesheet. No tubesheet crevice indications were observed in either the hot or cold legs of any of the generators inspected. The pertinent statistics are summarized in TAble A-2. For the case where

the only positive average incremental thinning increase was observed (steam generator B cold leg) the actual data from which the average was calculated are given in Table A-3.

In addition, histograms (Figs. A-7 to A-11) are presented to graphically display the number of indications observed over each 5% incremental change in eddy current readings between the May, 1980 and December, 1980 inspections for those tubes for which readings equal to or greater than 20% were reported in both inspections. No histogram was prepared for the steam generator C hot leg data since only one tube could be compared for the two inspections.

From Table A-2, it is noted that except for the cold leg of steam generator B, where a positive average increment was calculated, and the hot leg of steam generator C, where only a single comparison was possible, the remaining four comparisons yielded apparently negative average incremental thinning for the period from May, 1980 to November, 1980. This result is not indicative of an actual decrease in tube thinning. Rather, it reflects the variability in the eddy current method itself as well as possible human factors involved in evaluating the eddy current signals. However, in each case (Steam Generator A, hot and cold leg; Steam Generator B, hot leg; and Steam Generator C, Cold Leg), these results suggest little or no thinning has occurred in the time period studied.

In the case of Steam Generator C, hot leg, where only one indication could be compared between the two inspection periods, only seven indications ≥20% were observed, suggesting a low degree of thinning activity.

V. DISCUSSION

In the case of Steam Generator B, cold leg, comparison of the average incremental thinning increase with results from the other steam generator legs suggests that there may be a small but finite increment in tube thinning which may not be explainable solely on the basis of inherent uncertainties in the eddy current method. However, comparisons of the May, 1980 and November, 1980 eddy current signals from the pluggable tubes suggest that the presence of new or increased denting

current phase angles leading to possible overestimates of the depth of penetration in some of the December, 1980 signals.

Photographs of the November, 1980 eddy current signals from all of the plugged tubes, comparing November, 1980 eddy current signals with previous inspections, are shown in Figs. A-12 to A-33. In most of the photographs, denting can be seen to have affected the nature of the eddy current signals. For example, in Figure A-20, the eddy current signals and estimated wall thinning(%) for tube R22-C44 are displayed for the 4/79, 5/80 and 11/80 inspections. The component of the eddy current signal due to denting (indicated by arrows marked "1" on the figures) is seen to have increased in each of the inspections. The effect of the contribution of denting to the signal is to rotate, or deflect the portion of the signal associated with wall penetration (indicated by arrows marked "2" on the figures) toward higher phase angles, or greater apparent wall penetration.

In the present state of the art of eddy current inspection techniques, the effect of superimposition of denting and thinning signals cannot be quantified. Nevertheless, based on the above discussion of the nature of generation of the observed eddy current signals, it is believed that the actual tube wall penetration for many of the (plugged) tubes may be significantly less than has been reported.

Similar effects were observed for at least 12 of the 16 pluggable tubes in this leg of Steam Generator B, including R17-C69, for which the largest apparent increase of wall thinning was calculated from the reported field data, as well as for the pluggable tubes found in the other two steam generators.

On the basis of the highest calculated average incremental change from May, 1980 to December, 1980, 8.41% in SG/B cold leg, the apparent degradation for this period of operation consisting of 4.75 Effective Full Power Months (EFPM) is 1.77%/EFPM. Assuming the same rate of thinning over the present operating period, a tube operating with the largest unplugged indication of 39% might experience further wall loss of 10.6% over an additional operating period of 6 EFPM. Allowing for the staff's

estimate of 9% for errors attributable to the eddy current method*, such a tube might show an indication of 59% in terms of wall penetration after 6 EFPM of operation. The remaining wall ligament would then consist of 41% of the original wall thickness.

As shown in Appendix B to this submittal, the minimum wall requirement for postulated accident conditions for straight sections of the tube is 0.013 inches, or 26% of the nominal 0.050 inch tube wall. This limit would permit operation for up to 14.7 EFPM at the calculated rate of degradation, i.e. 1.77% per EFPM. Further, if the tubes plugged in steam generator B, cold leg, are deleted (on the basis that these tubes have been removed from service) from the data base (Table A-3) from which the calculations were made to determine the highest average thinning rate, the calculated average incremental thinning would be only 6.25% rather than 8.41%, and the thinning rate calculated over 4.75 EFPM would be only 1.32% EFPM rather than the conservatively calculated 1.77% EFPM. Using a thinning rate of 1.32% EFPM, and following the same method of calculation described above, margin is available for operation to 19.7 EFPM. Thus, ample margin is available for operation in excess of 6 additional EFPM even given the conservatisms assumed.

VI. VERIFICATION OF INSPECTION COVERAGE

A review will be made to verify that all unplugged tubes with reported indications ≥ 20% in previous inspections will be inspected at the next outage.

* However, Westinghouse believes that for indications in the range of 40 - 50%, a lower estimate, i.e. about 7%, is more appropriate for errors attributable to the eddy current method.

WORK SHEET
WESTINGHOUSE FORM 8295 E

TURKEY POINT UNIT #4 EDDY CURRENT INDICATIONS FROM TUBES PLUGGED FOR THINNING-NOVEMBER, 1980 STEAM GENERATOR INSPECTION

STEAM GENERATOR	TUBE # Row	Col.	Eddy Current Indications For Inspections Tested	8/74	5/75	4/76		5/77	8/78	4/79	5/80	11/80		
A (HL)	9	21		33	38	38						45		
" "	11	22		22	<20							58		
" "	6	75			27							62		
B (HL)	9	81			<20	<20						51		
B (CL)	14	29			36	38		27	21	39	33	46		
" "	12	30			36	28		27	23	35	35	53		
" "	23	39			39	32		21	<20	NDD**		43		
" "	24	39				36		29	23	38	31	44		
" "	24	40			36	27		21	23	<20	24	41		
" "	11	44			27	27		27	29	24	36	53		
" "	22	44			21	31		24	27	28	28	45		
" "	10	46			<20	<20					37	45		
" "	11	46			<20	<20					39	43		
" "	13	46									33	51		
" "	22	46			34	35		32	36	32	32	47		
" "	23	46			34	34		28	32	35	32	41		
" "	10	47								22	39	47		
" "	7	62			37	35		30	30	31	37	42		
" "	7	64			25	25		22	<20	NDD		57		
" "	7	65			32	29		27	<20			42		
" "	17	69			29	23		27	23	20	22	44		
C (HL)	14	53		25	36	21		<20				49		
" "	44	53										51		
C (CL)	10	46			32	21		35	34	31	31	44		
C (CL)	5	58			27				29	30	33	44		

** NDD=No Detectable Defect

TABLE A-2

SUMMARY OF TURKEY POINT UNIT #4 STEAM GENERATOR TUBING INCREMENTAL WASTAGE FROM MAY, 1980 TO November, 1980

	S/G A		S/G B		S/G C	
	HL	CL	HL	CL	HL	CL
Average incremental wastage (% wall thickness)	-3.82%	-2.23%	-1.14%	8.41%	3%	-1.65%
Number of Tubes Compared	11	219	21	46	1	132
Standard Deviation	3.0	4.1	5.9	6.4	-	4.5

TABLE A - 3

TURKEY POINT UNIT #4

STEAM GENERATOR B COLD LEG

Tubes With ≥ 20% Eddy Current Indications in Both 11/80 and 5/80

Tube I.D. R	Tube I.D. C	5/80 Indication (%)	11/80 Indication (%)	Change (%)
14	29	33	46	13
12	30	35	53	18
18	36	32	36	4
15	37	24	39	15
23	38	23	28	5
24	39	31	44	13
24	40	24	41	17
23	43	25	39	14
11	44	36	53	17
22	44	28	45	17
21	45	24	32	8
7	46	29	37	8
8	46	27	32	5
10	46	37	45	8
11	46	39	43	4
13	46	33	51	18
15	46	25	28	3
21	46	22	30	8
22	46	32	47	15
23	46	32	41	9
24	46	28	38	10
25	46	25	36	11
8	47	28	38	10
10	47	39	47	8
24	47	31	39	8
26	47	21	29	8

TABLE A - 3 (Cont'd)

TURKEY POINT UNIT #4

STEAM GENERATOR B COLD LEG

Tubes With ≥ 20% Eddy Current Indications in Both 11/80 and 5/80

Tube I.D. R	Tube I.D. C	5/80 Indication (%)	11/80 Indication (%)	Change (%)
9	48	37	39	2
10	48	21	31	10
12	48	33	32	-1
23	48	21	38	17
24	48	30	38	8
25	48	34	38	4
26	48	27	35	8
10	49	24	33	9
24	49	30	39	9
23	50	28	39	11
24	50	32	36	4
8	56	27	21	-6
7	62	37	42	5
9	62	24	35	11
17	62	31	32	1
18	63	31	37	6
8	67	37	29	-8
8	68	32	28	-4
17	69	22	44	22
7	71	22	27	5

Total number of tubes compared = 46

Average change = 8.41%

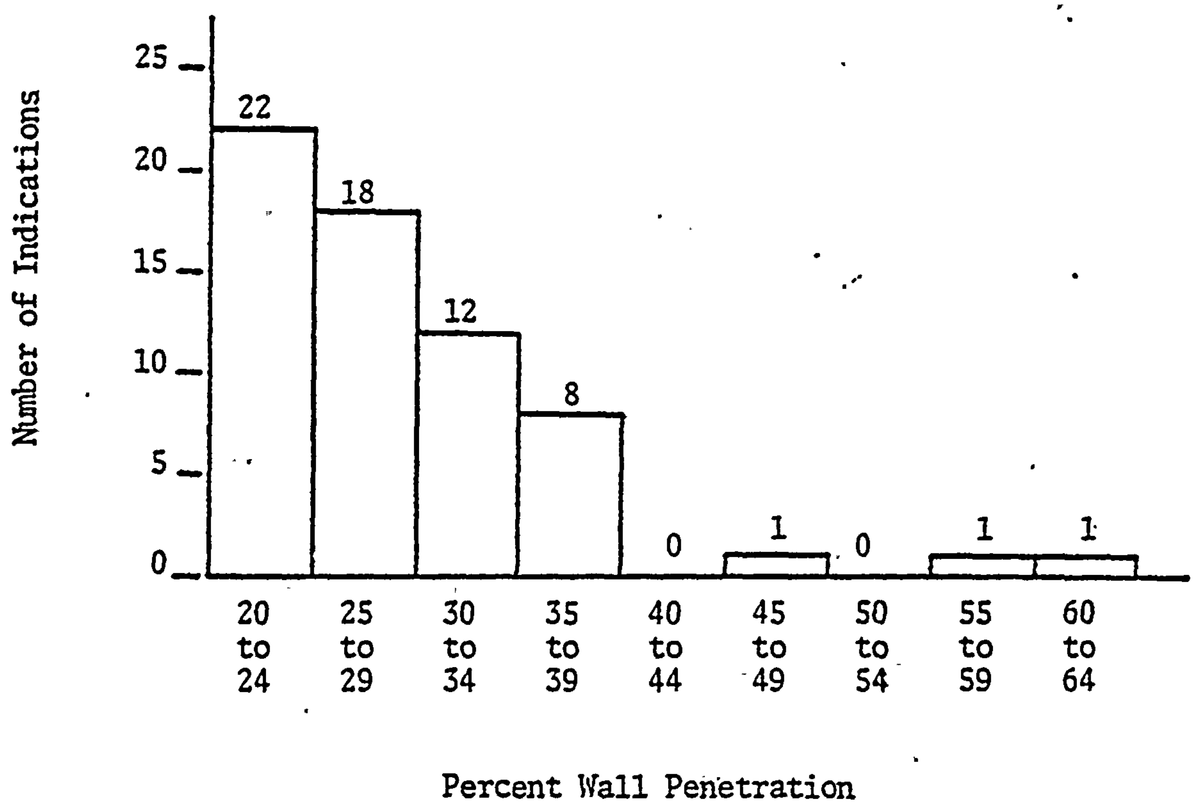
Standard Deviation = 6.38

FIGURE A - 1

TURKEY POINT 4

S/G A HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION



TURKEY POINT 4

S/G A COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION

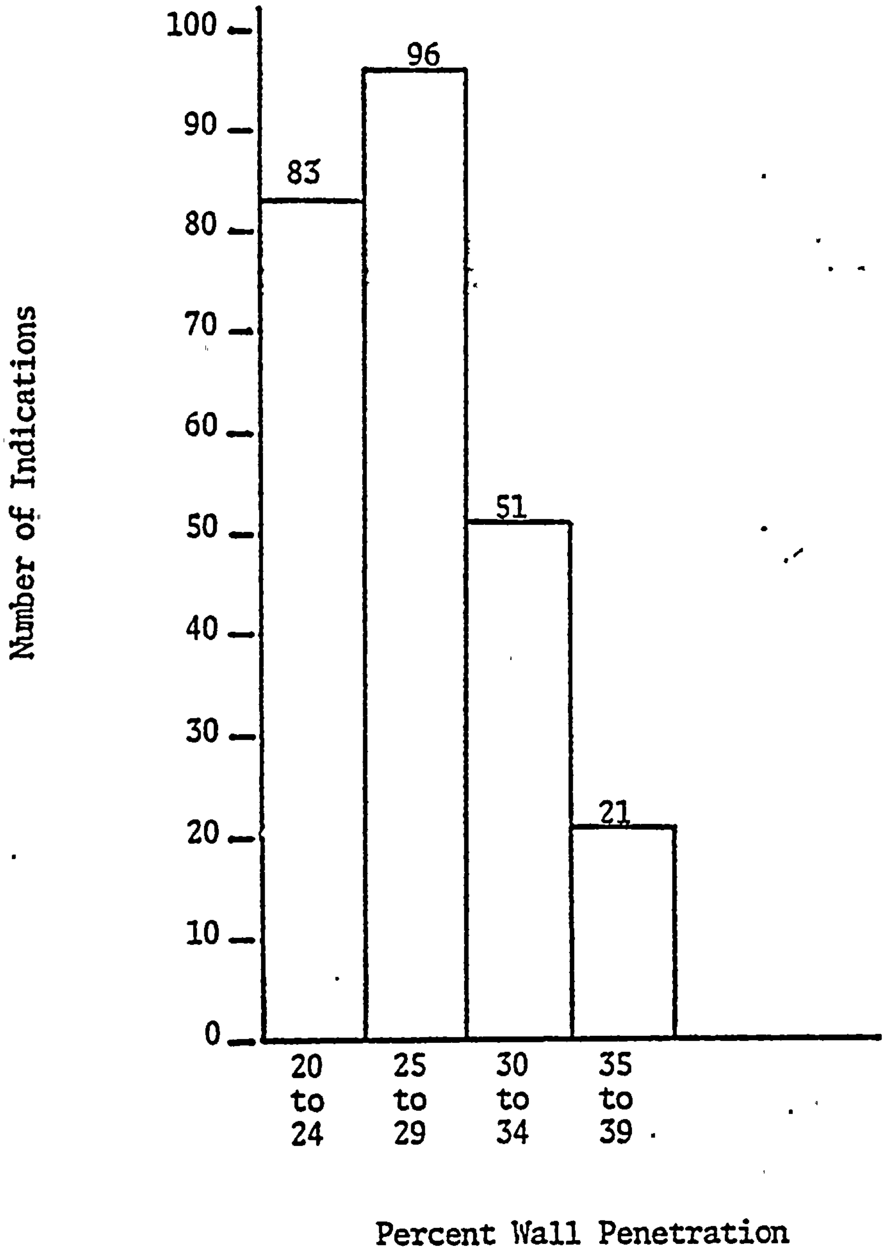


FIGURE A - 5

TURKEY POINT 4

S/G B HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%

NOVEMBER 1980 INSPECTION

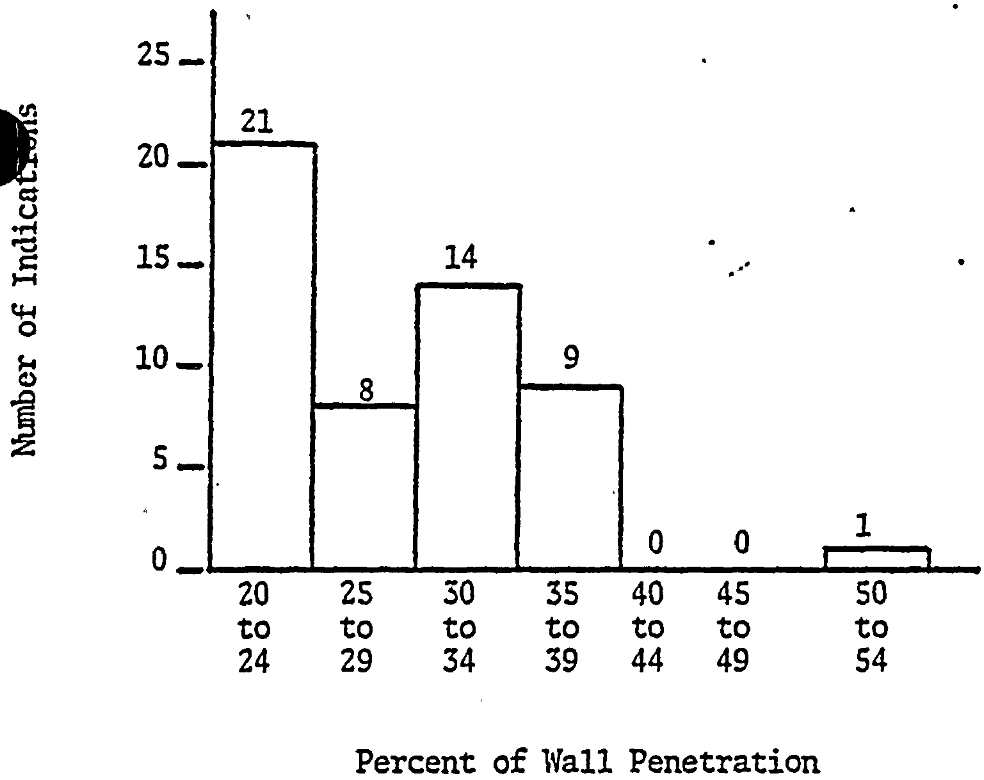
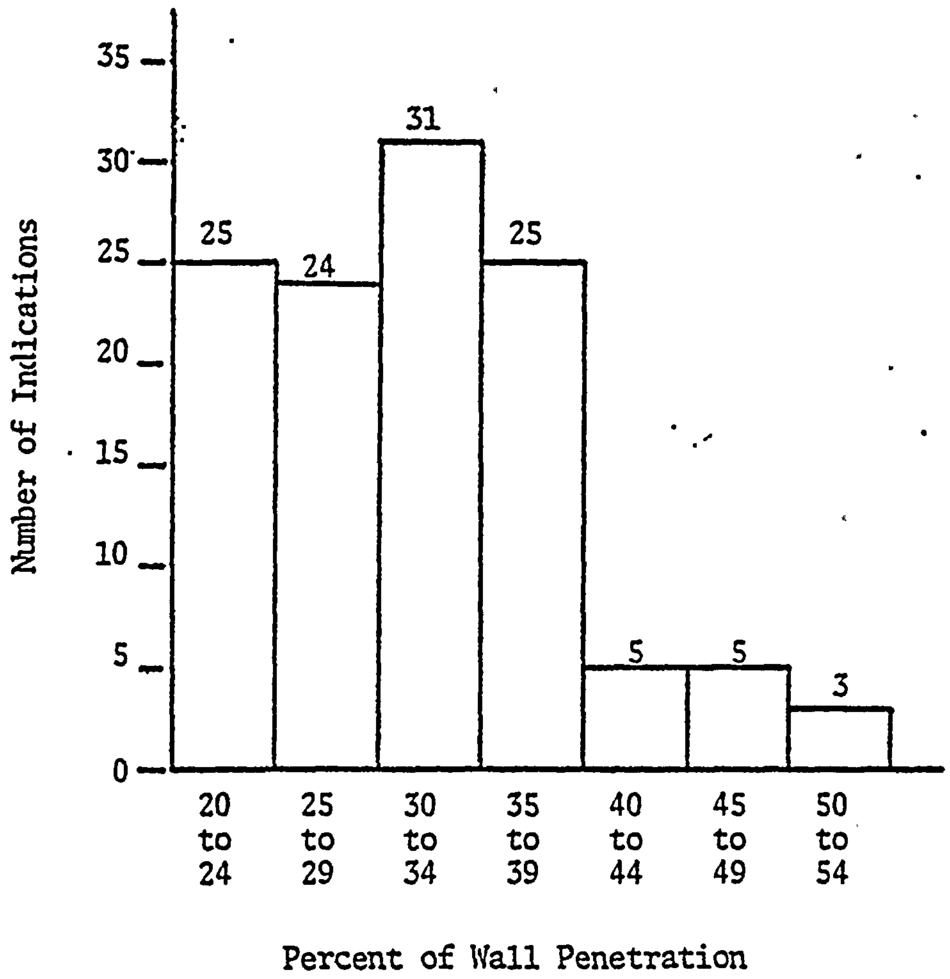


FIGURE A - 4

TURKEY POINT 4

S/G B COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION



TURKEY POINT 4

S/G C HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%

NOVEMBER 1980 INSPECTION

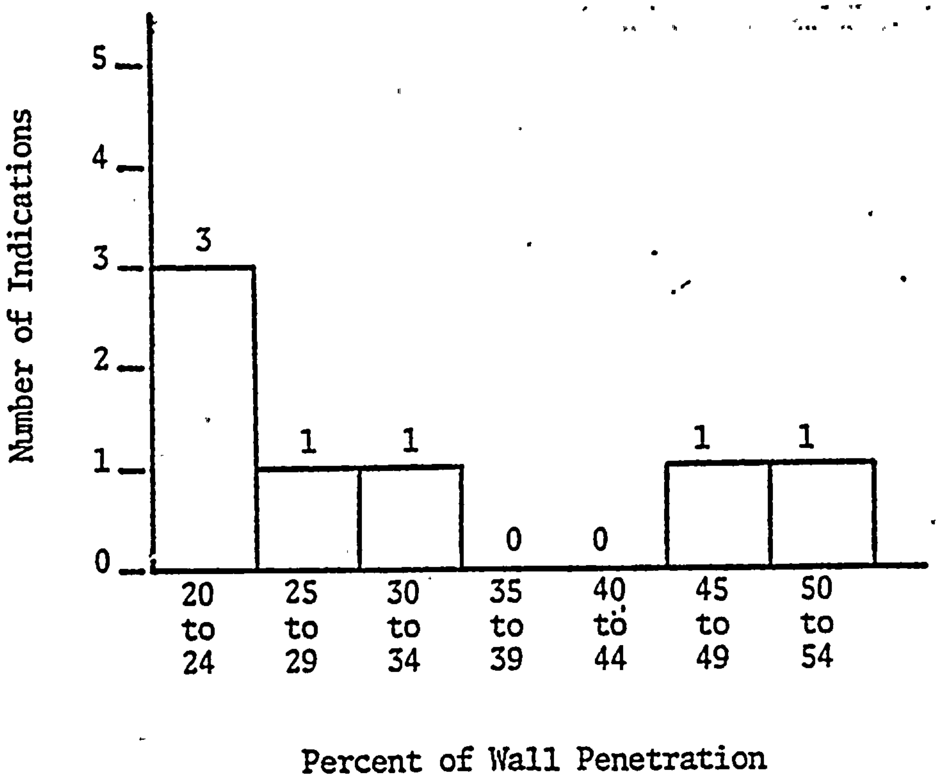


FIGURE A - 6

TURKEY POINT 4

S/G C COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%

NOVEMBER 1980 INSPECTION

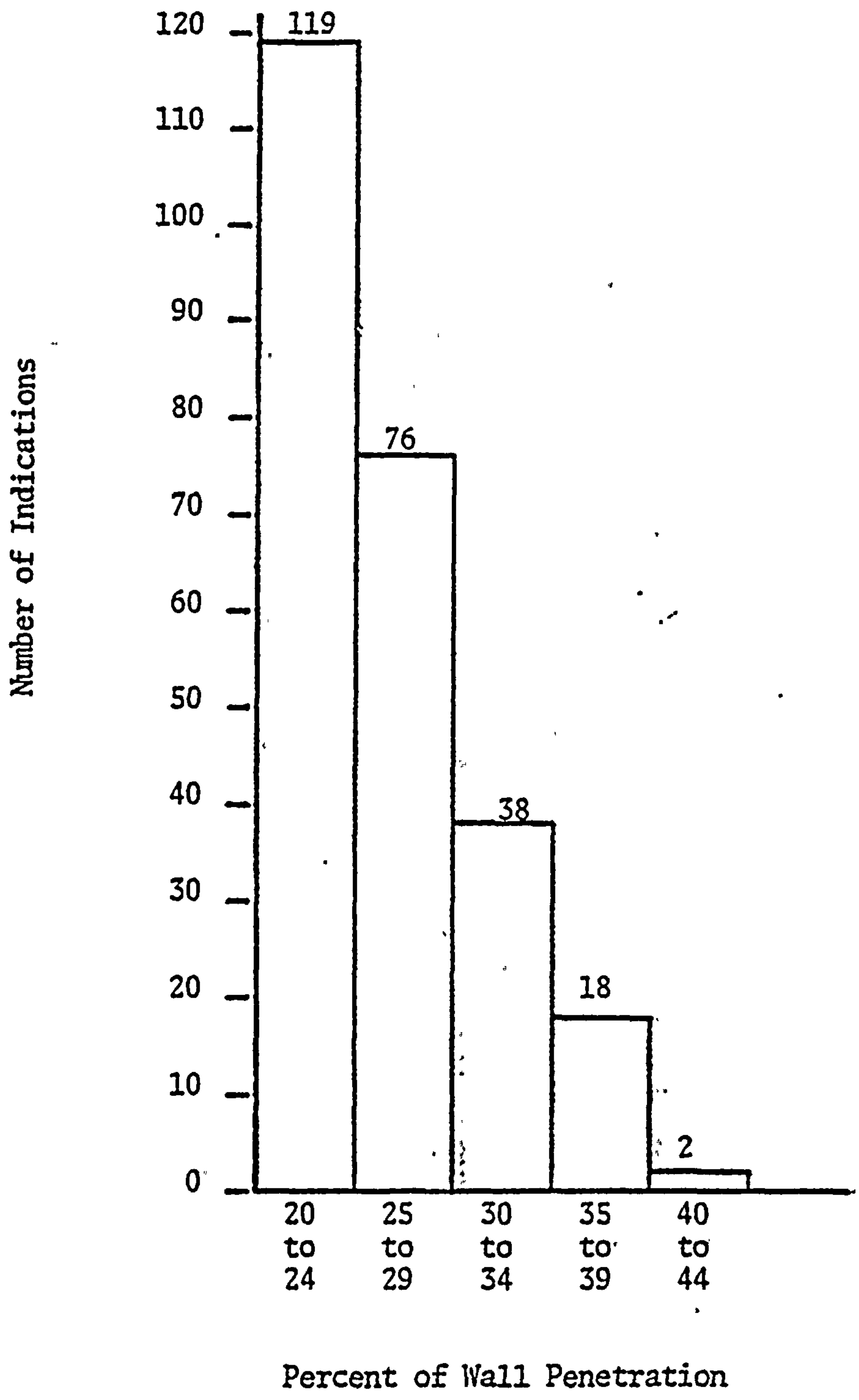


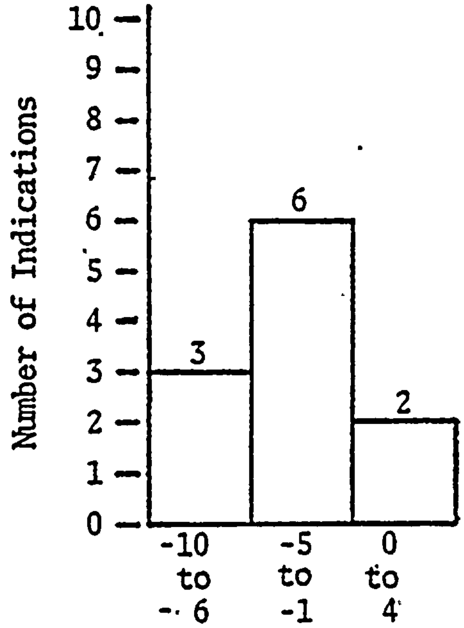
FIGURE A - 7

TURKEY POINT 4

S/G A INLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points 11
Average Change -3.82



Range of Change
% of Wall Thickness

FIGURE A - 8

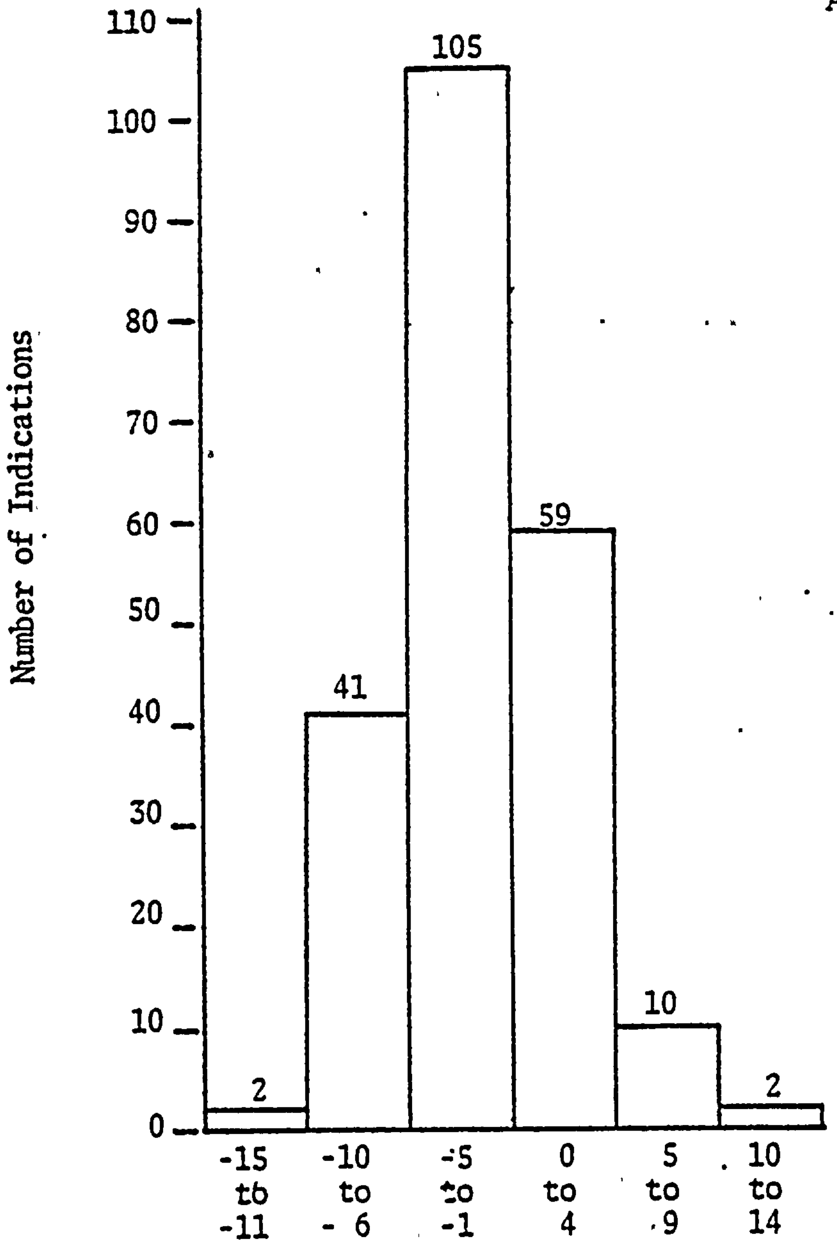
TURKEY POINT 4

S/G A OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Point 219

Average Change -2.23



Range of Change
% of Wall Thickness

FIGURE A - 9

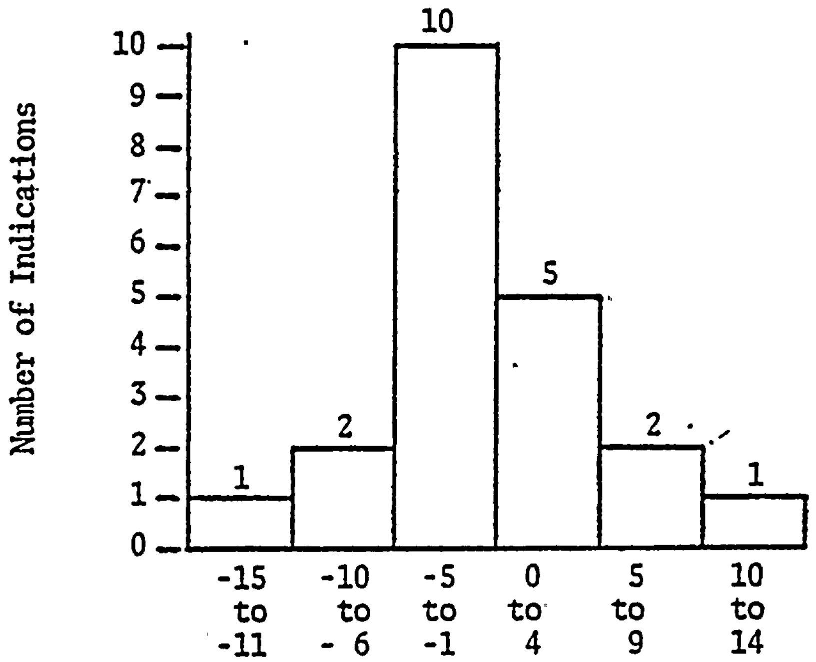
TURKEY POINT 4

S/G B INLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points 21

Average Change -1.14



Range of Change
% of Wall Thickness

FIGURE A - 10

TURKEY POINT 4

S/G B OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points	46
Average Change	8.41

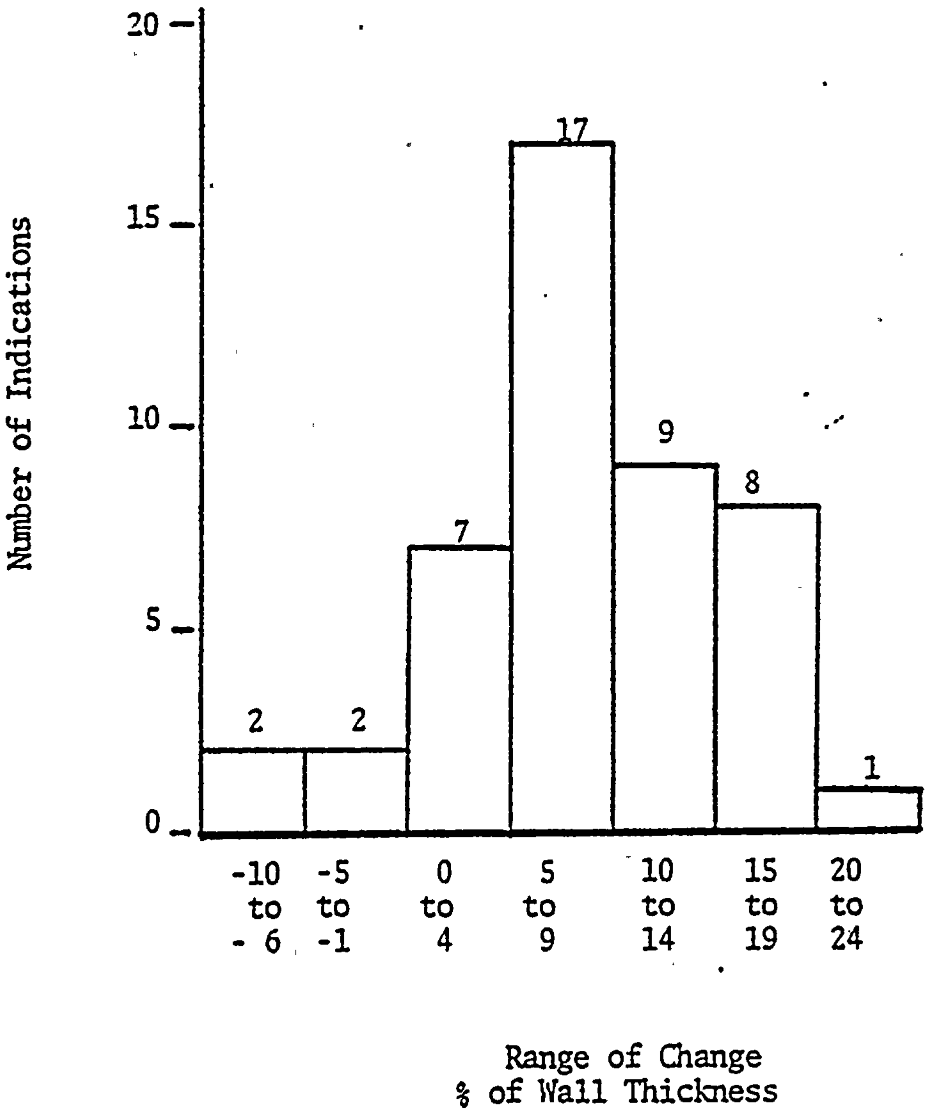


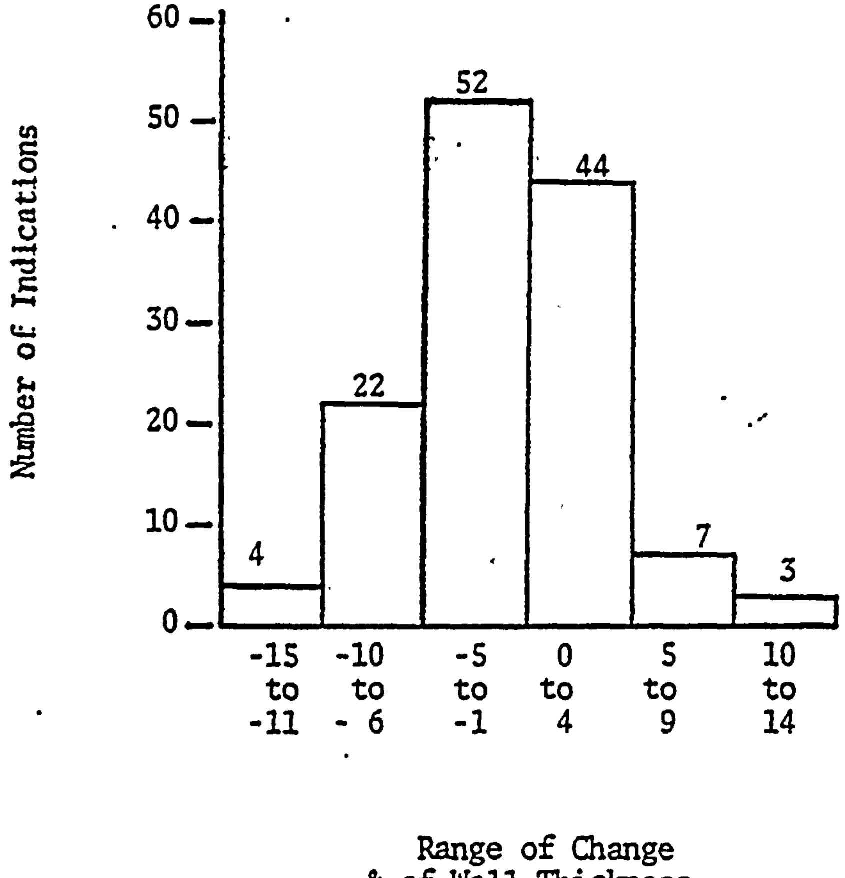
FIGURE A - 11

TURKEY POINT 4

S/G C OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points	132
Average Change	-1.65



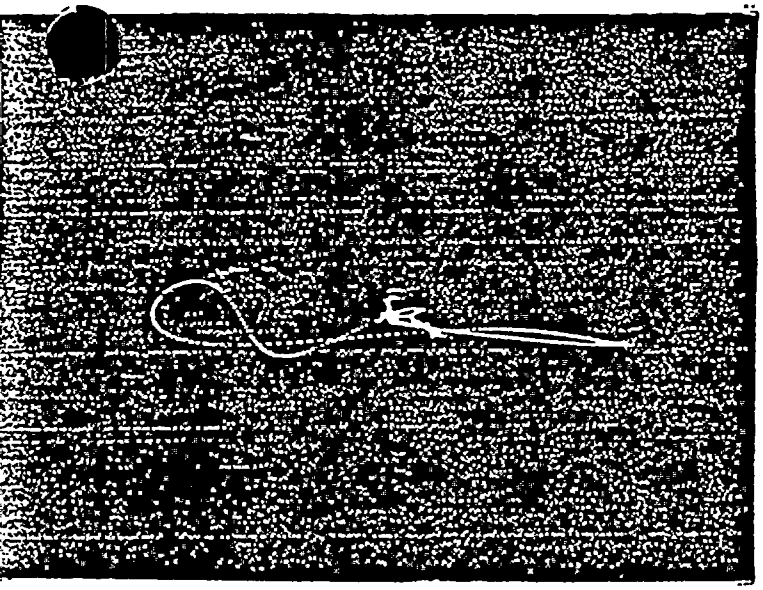
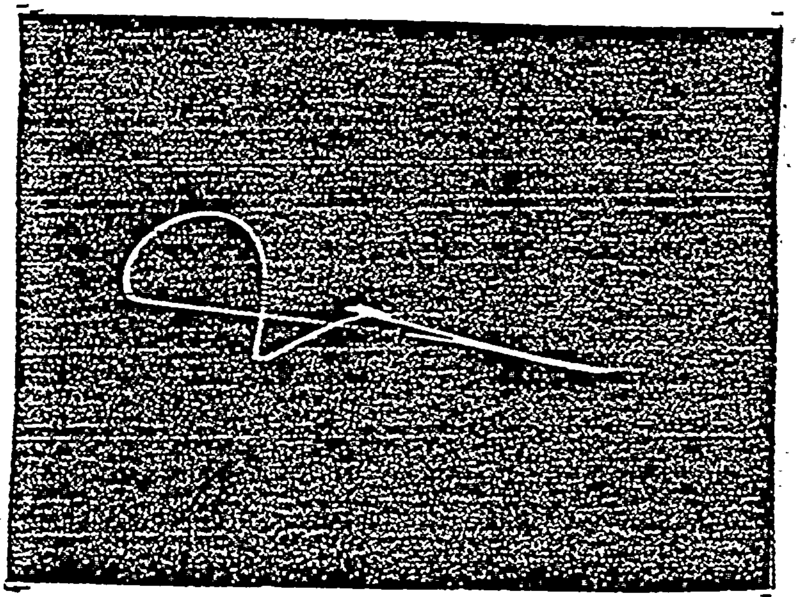
FIGURES A-12 to A-33

EDDY CURRENT SIGNALS FROM TUBES PLUGGED
IN NOVEMBER, 1980

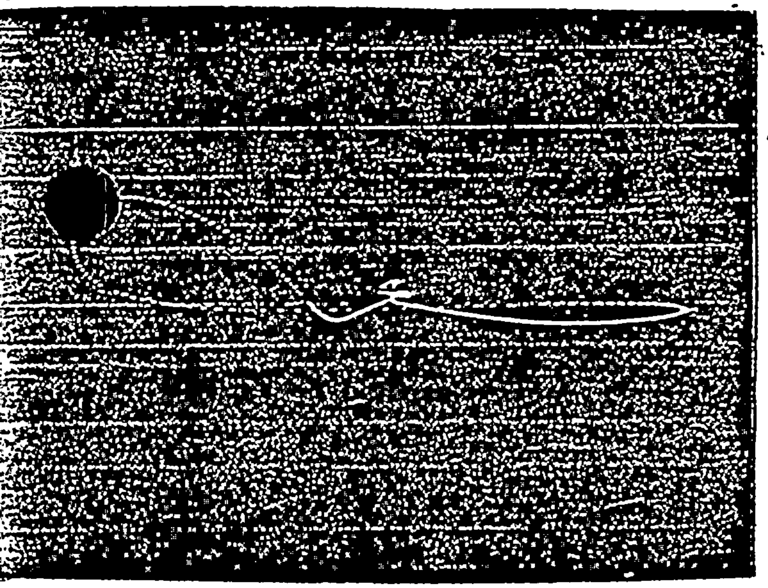
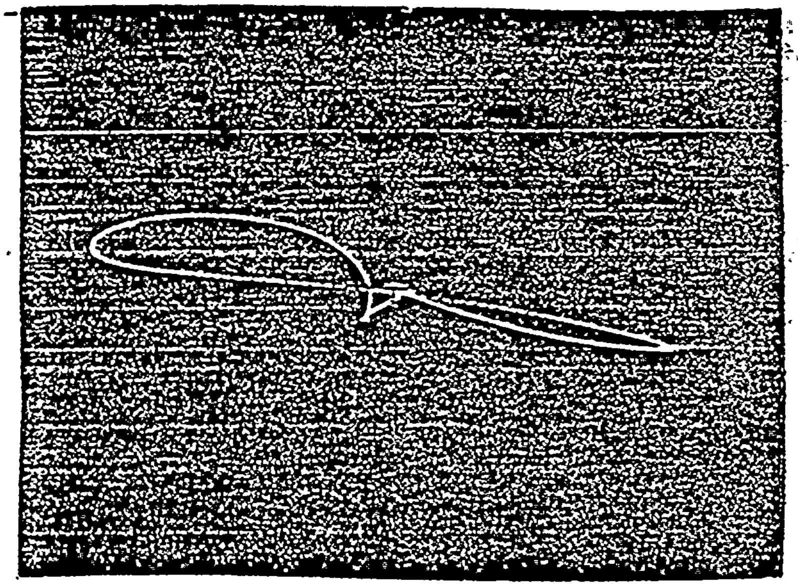
TURKEY POINT UNIT #4

TURKEY POINT #4 (FLA) FIG. A-12
S/G A H.L.

4/79 2 VOLTS/DIVISION 11/80

Not Quantified R6C75 62% TTS

Not Quantified R11C22 58% TTS

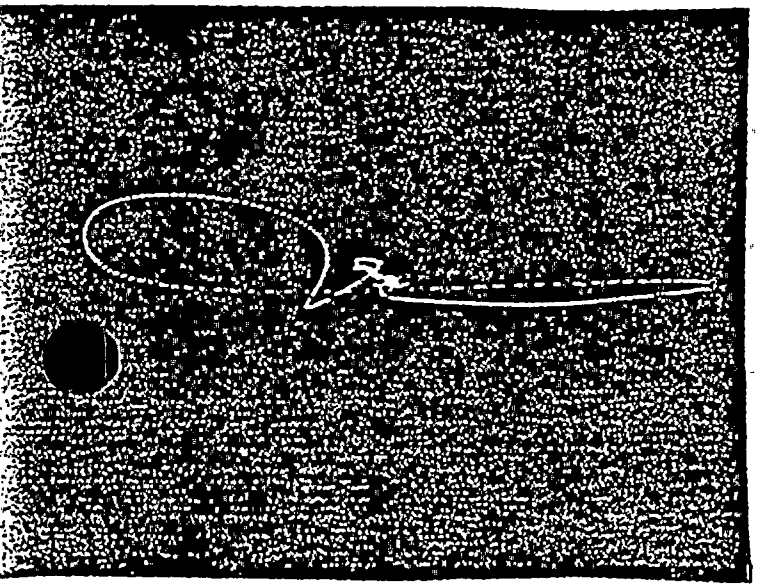
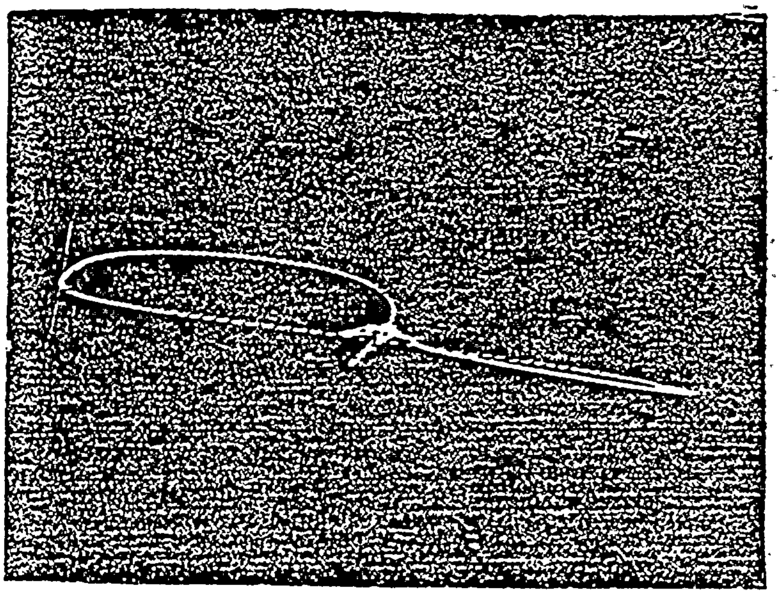
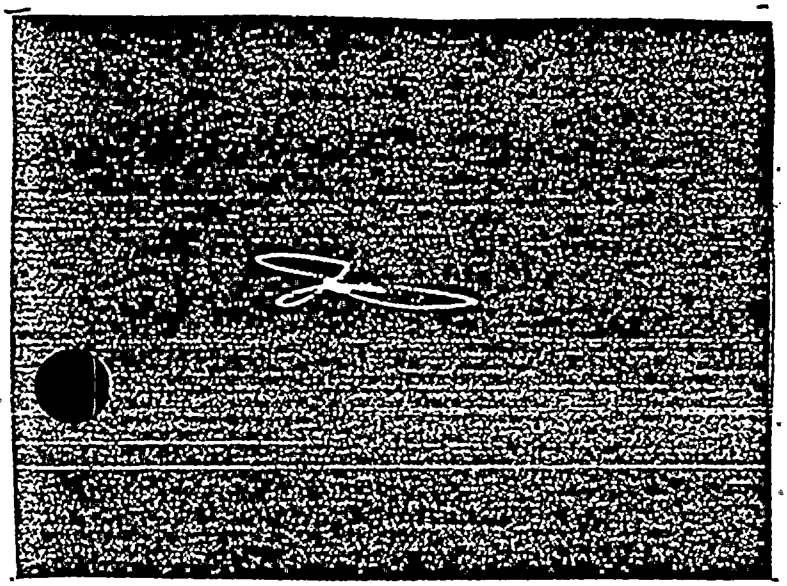



FIG A-13

TURKEY POINT #4 (FLA)

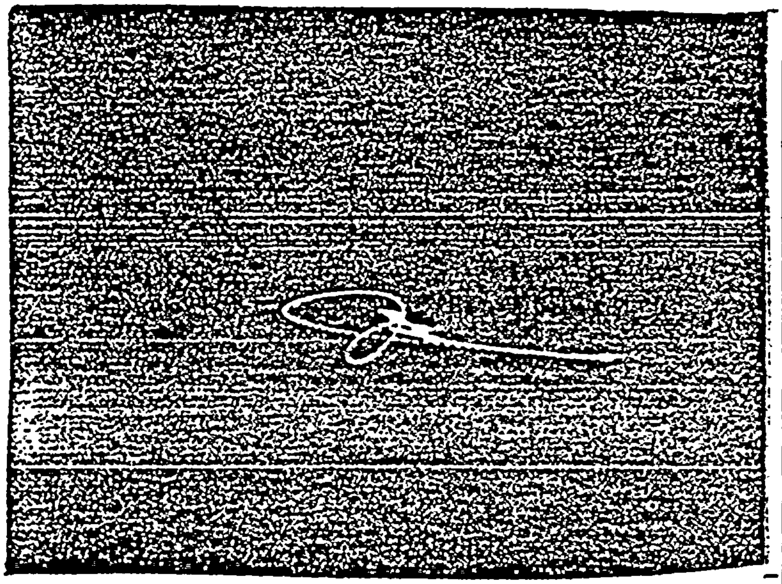
S/G B H.L.
2 VOLTS/DIVISION

4/79



Not Quantified R9C81

11/80



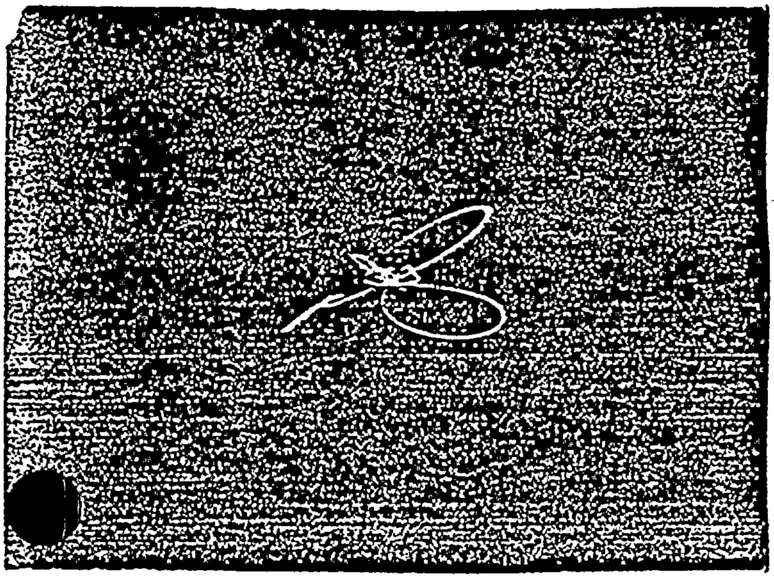
51% 1" ATS

TURKEY POINT #4(FLA)

S/G-B C.L.

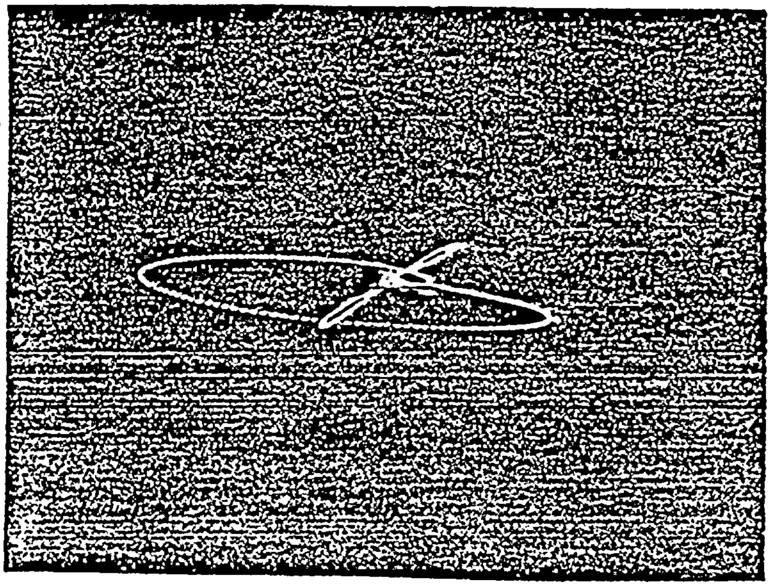
2 Volts/Division

4/79



39%

5/80

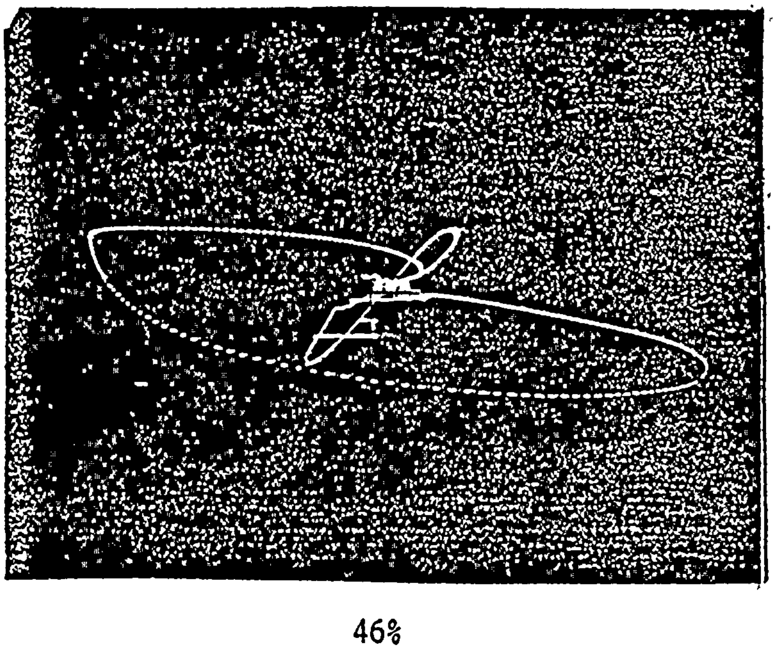


33%

R14C29

2" ATS

11/80



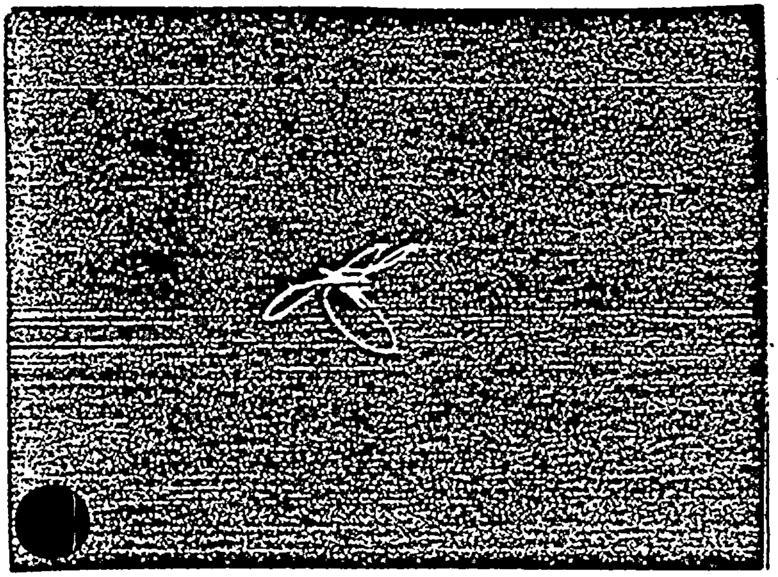
46%

TURKEY POINT #4(FLA)

S/G-B C.L.

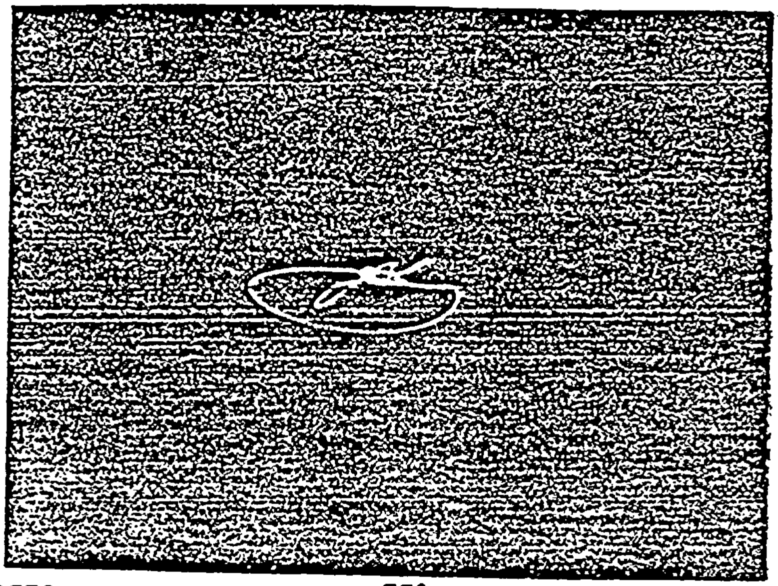
2 Volts/Division

4/79



35%

5/80

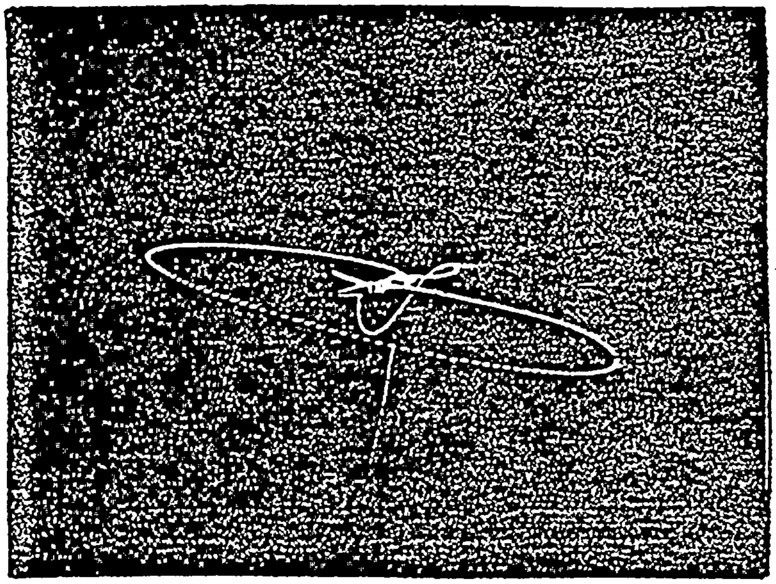


35%

R12C30

2" ATS

11/80



53%

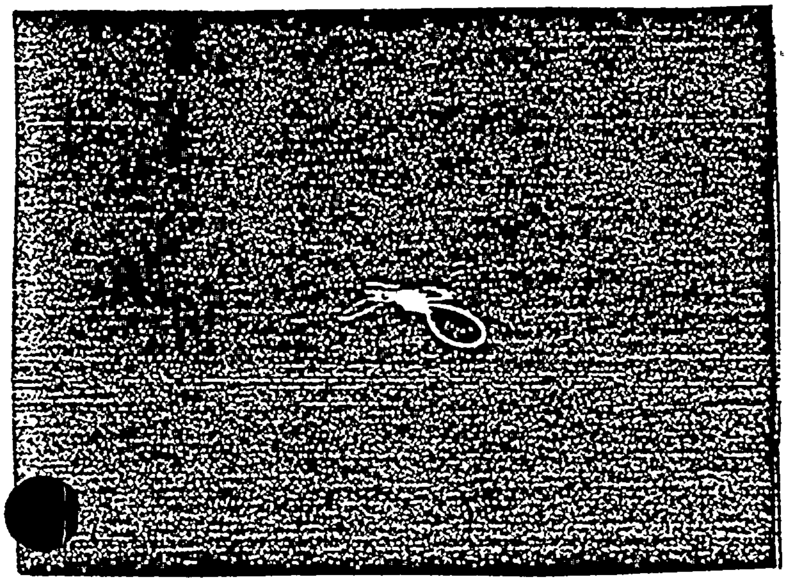
FIG. A-16

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

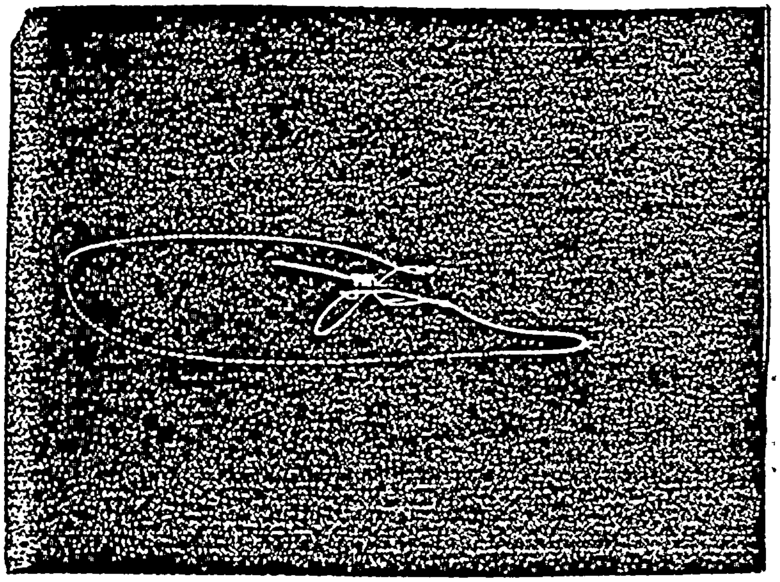
5/80

Not Tested

R23C39

2" ATS

11/80



43%

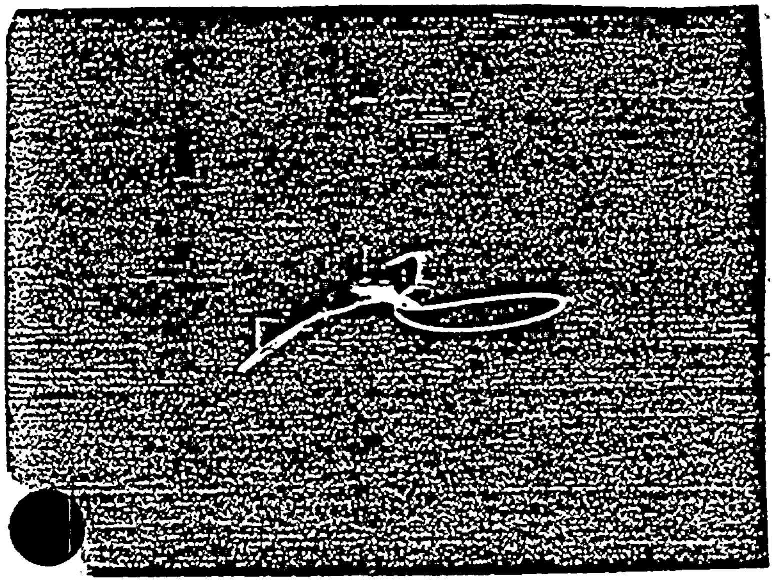
FIG. A-17

TURKEY POINT #4 (FLA)

S/G-B C.L.

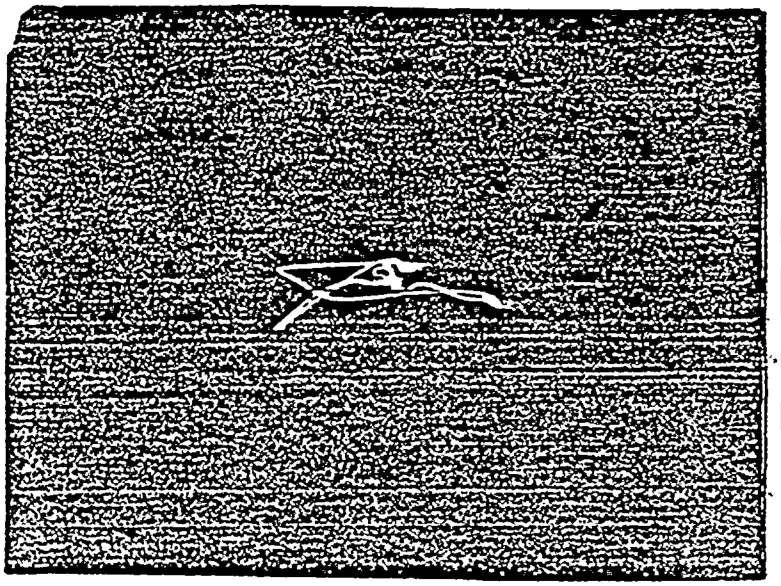
2 Volts/Division

4/79



38%

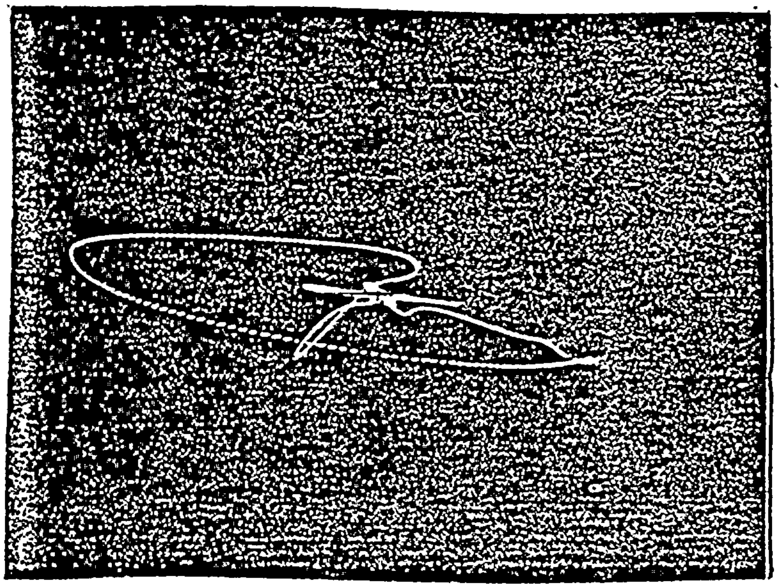
5/80



31 %

R24C39

1" ATS



44%

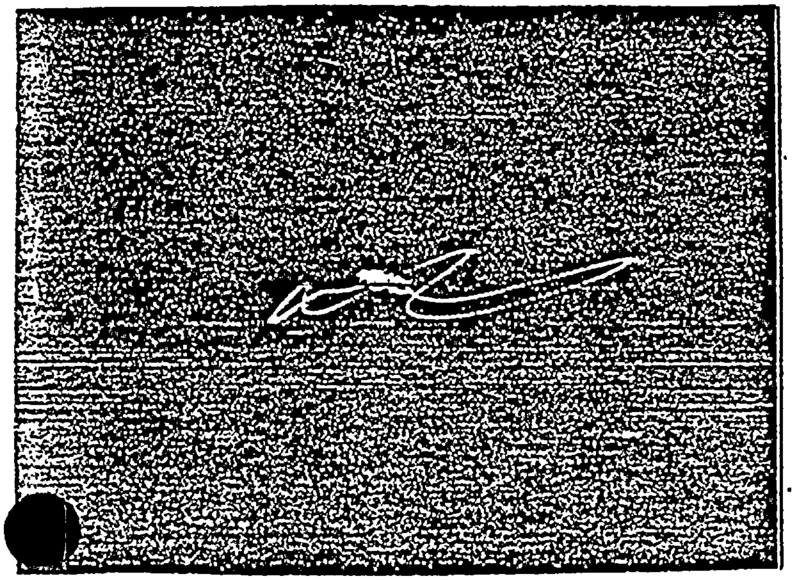
FIG. A-18

TURKEY POINT #4(FLA)

S/G-B C.L.

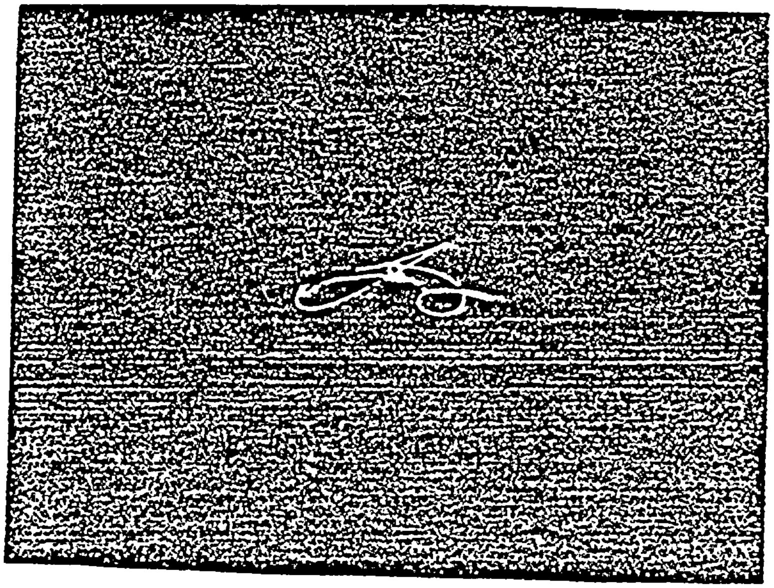
2 Volts/Division

4/79



< 20%

5/80

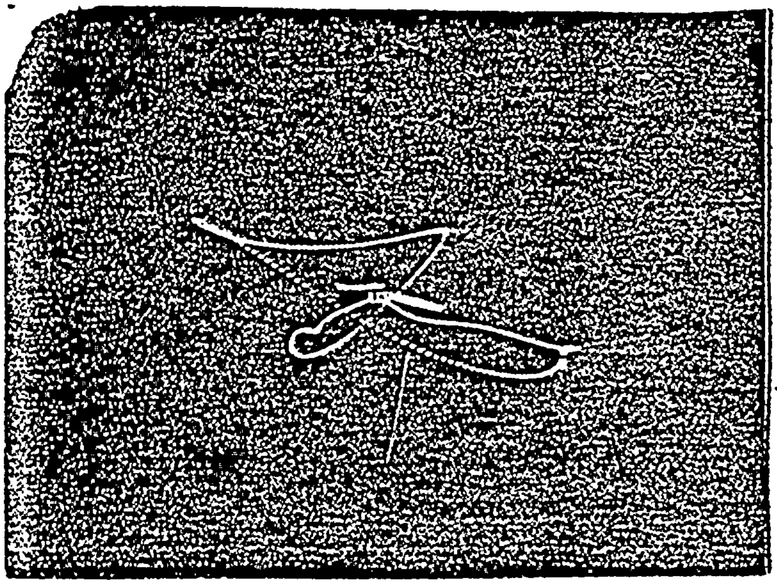


24%

R24C40

½" ATS

11/80



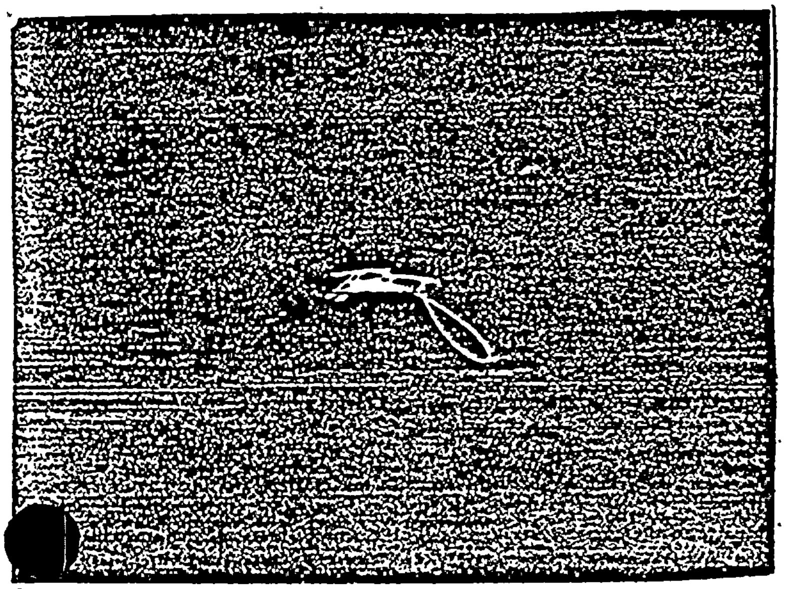
41%

TURKEY POINT #4(FLA)

S/G-B C.L.

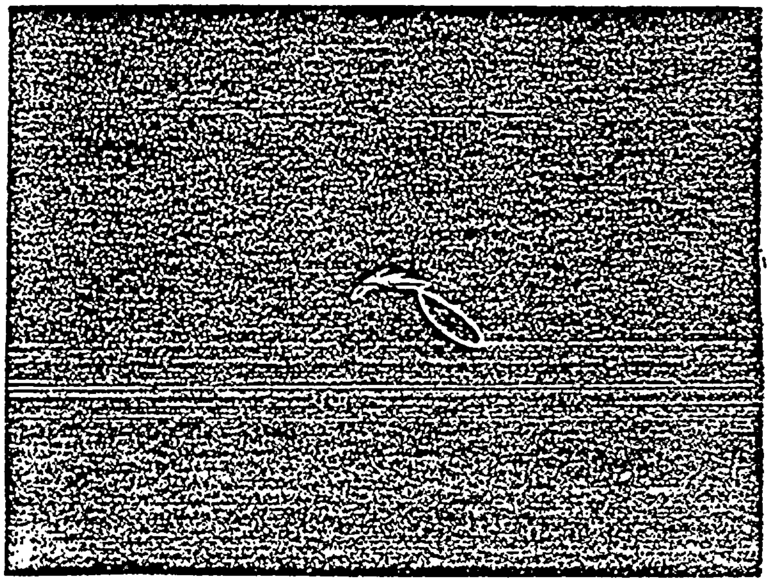
2 Volts/Division

4/79



24%

5/80

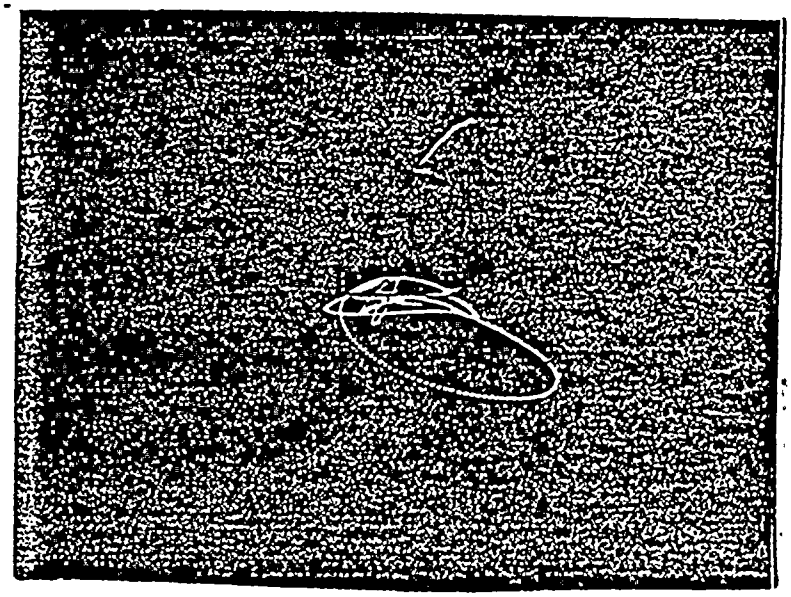


36%

R11C44

2" ATS

11/80



53%

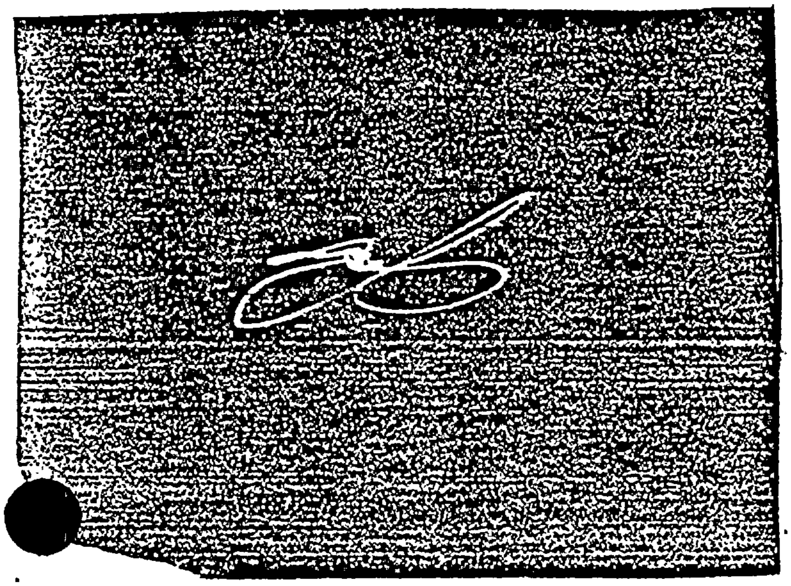
FIG. A-20

TURKEY POINT #4(FLA)

S/G-B C.L.

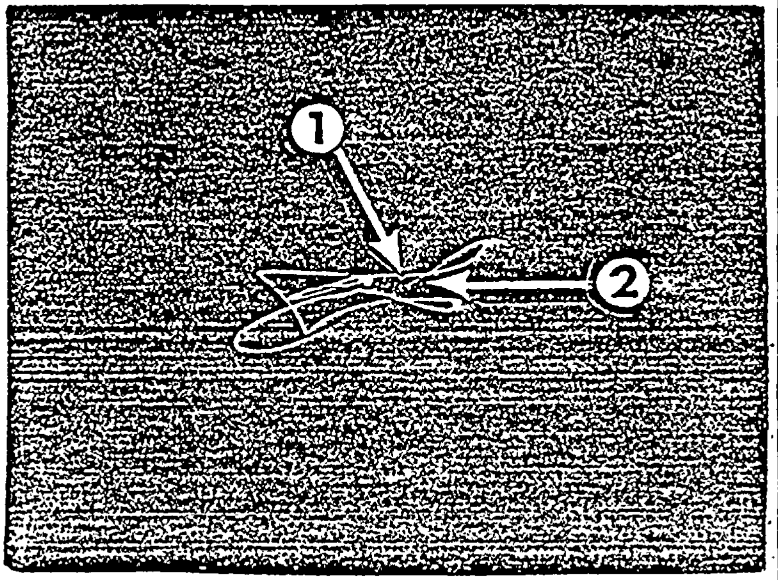
2 Volts/Division

4/79



28%

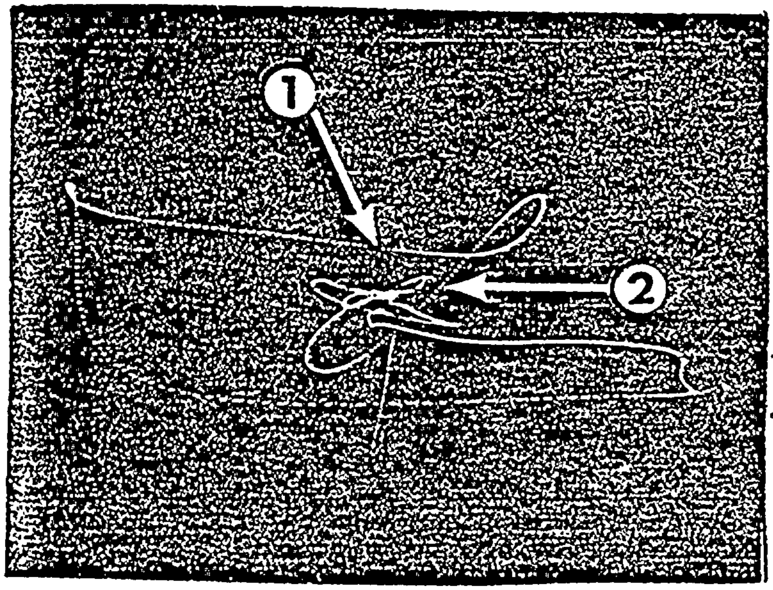
5/80



28%

R22C44
1" ATS

11/80



45%

FIG. A-21

TURKEY POINT #4(FLA)

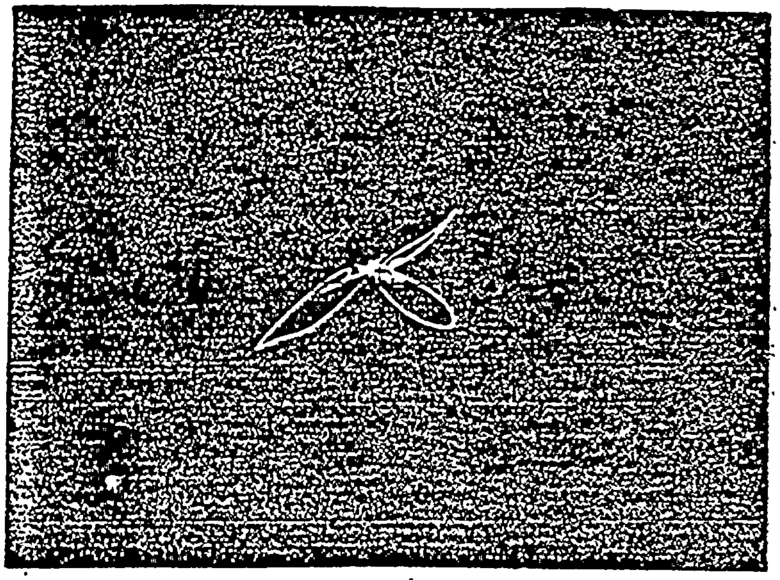
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

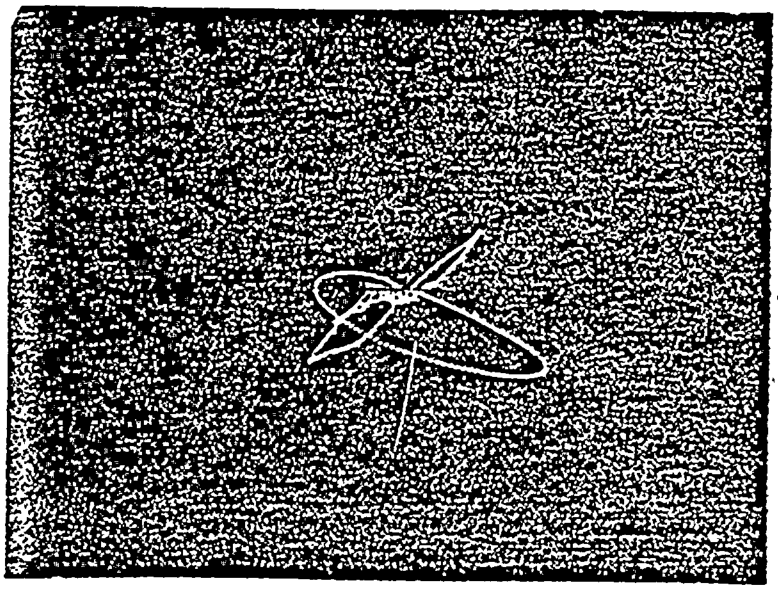
5/80



R10C46 37%

2" ATS

11/80



45%

FIG. A-22

TURKEY POINT #4(FLA)

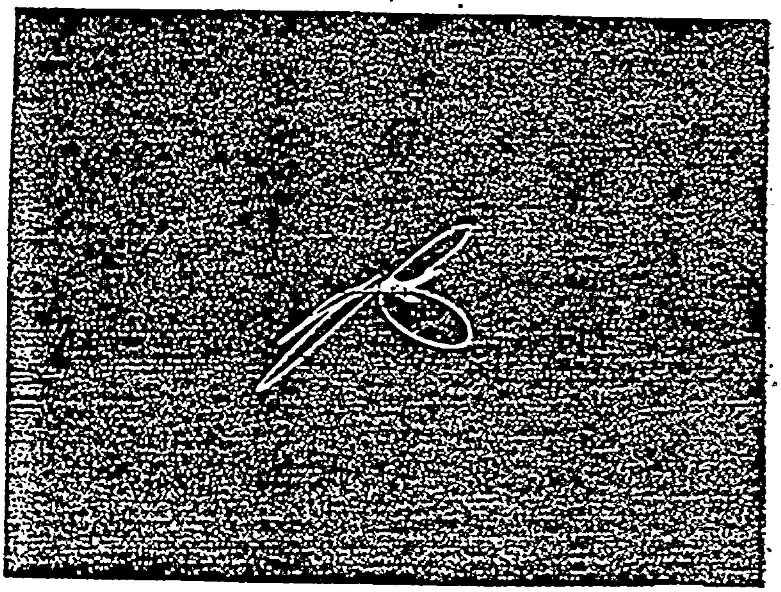
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

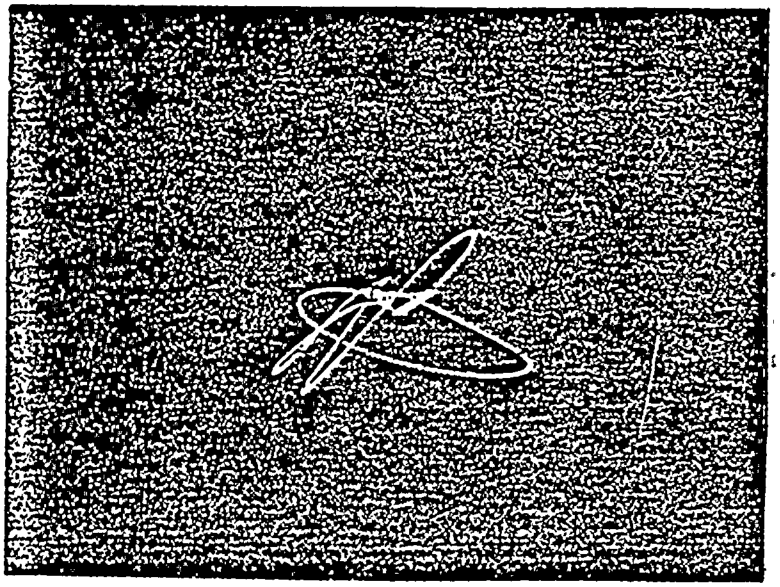
5/80



R11C46 39%

2" ATS

11/80



43%

TURKEY POINT #4(FLA)

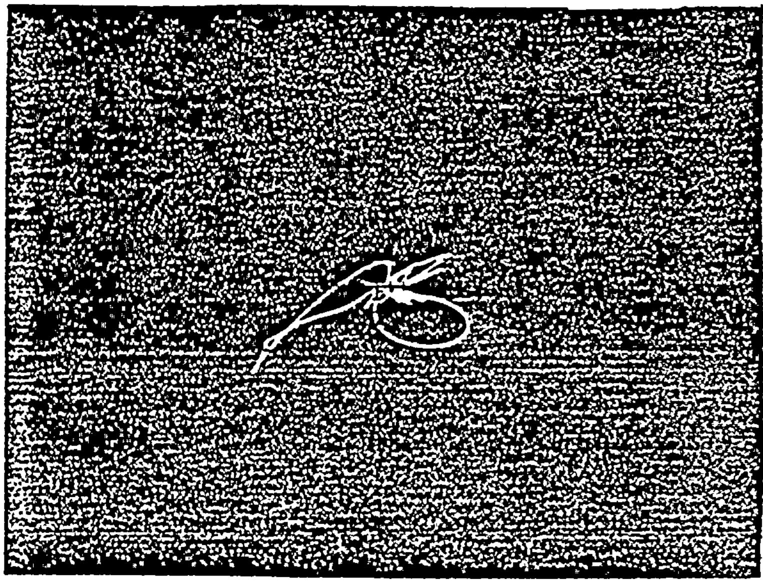
S/G-B C.L.

2 Volts/Division

4/79

NOT TESTED

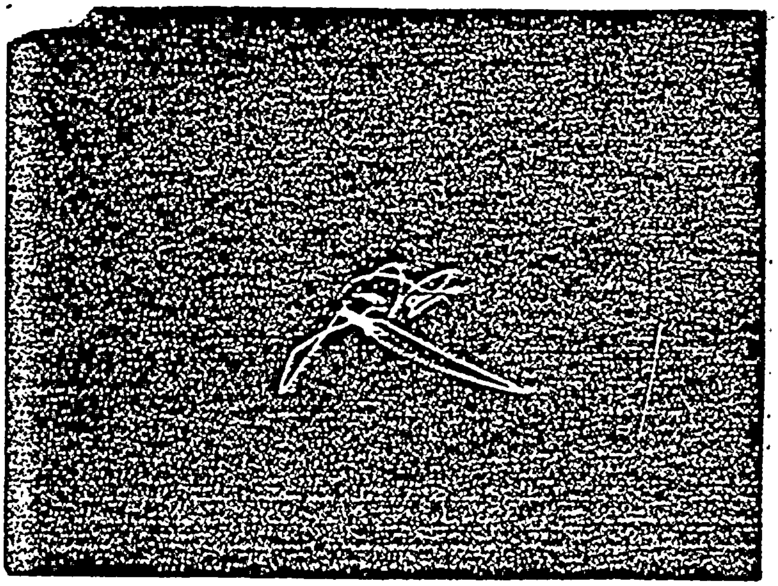
5/80



R13C46
3" ATS

33%

11/80



51%

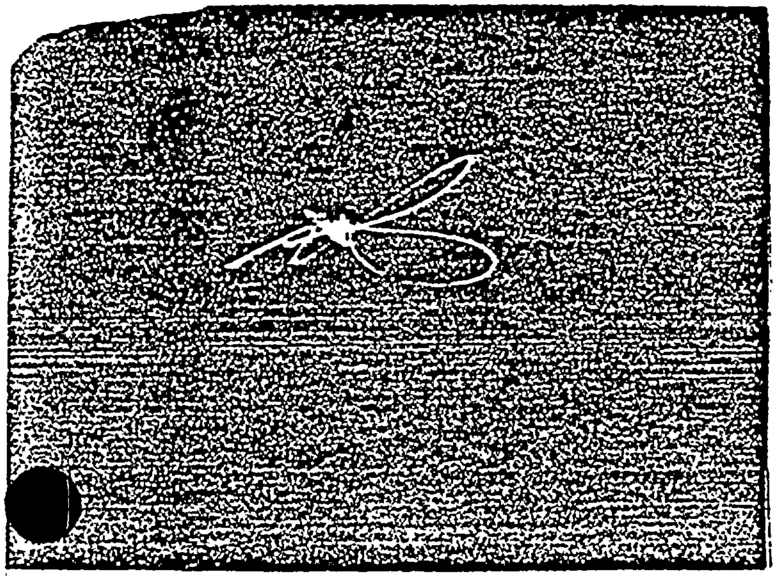
FIG. A-24

TURKEY POINT #4 (FLA)

S/G-B C.L.

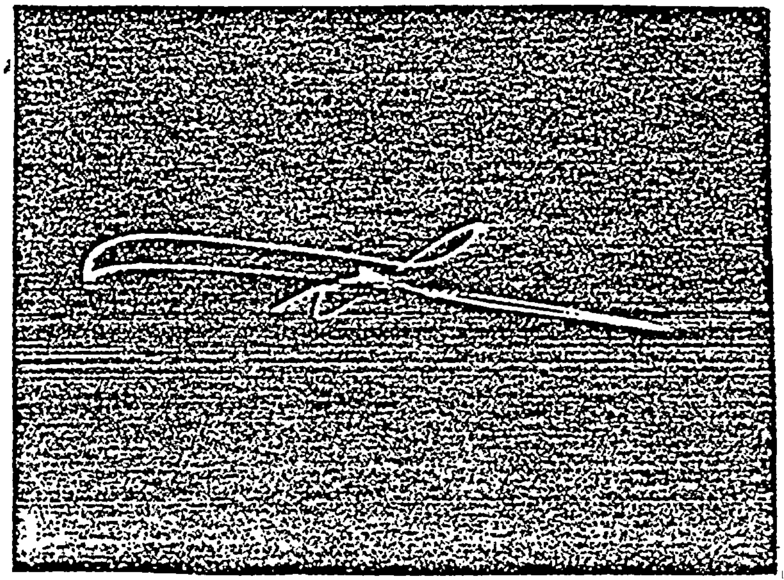
2 Volts/Division

4/79



32%

5/80

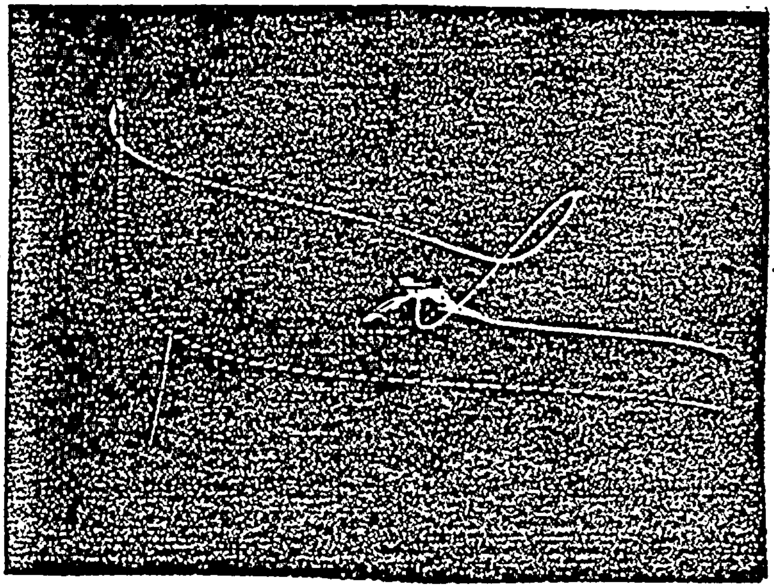


32%

R22C46

½" ATS

11/80



49%

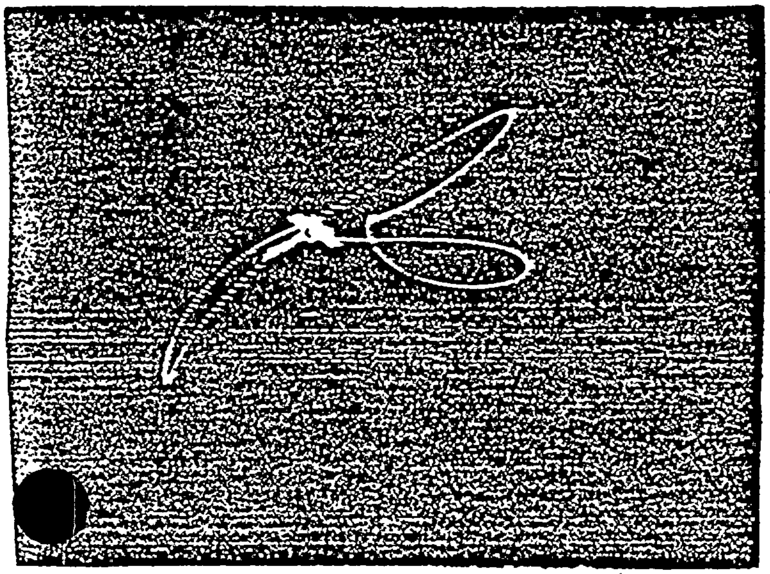
FIG. A- 25

TURKEY POINT #4(FLA)

S/G-B C.L.

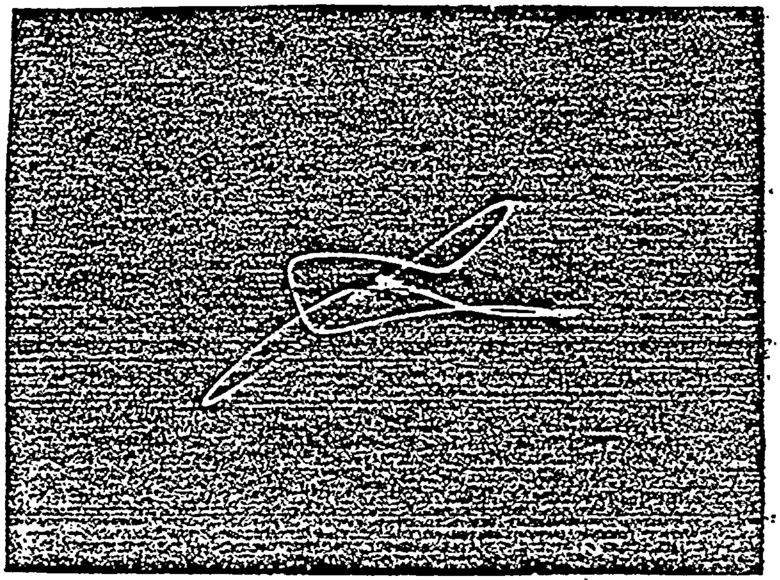
2 Volts/Division

4/79



35%

5/80

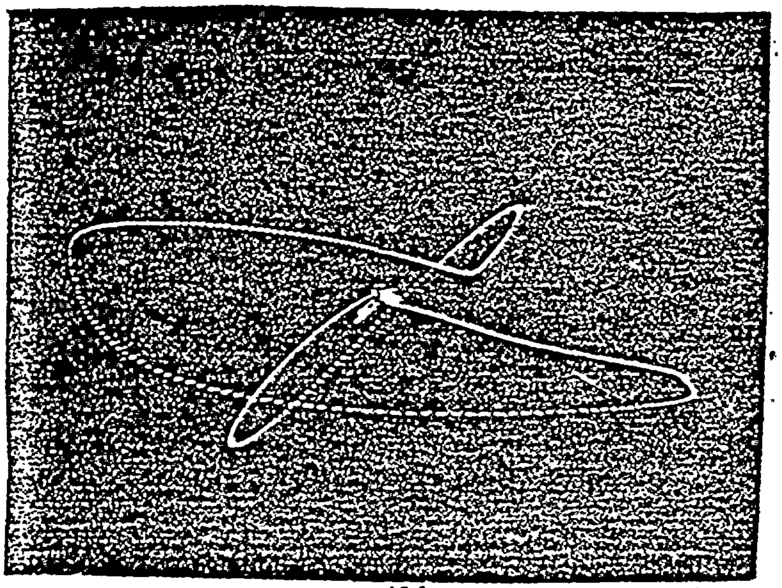


32%

R23C46

1" ATS

11/80



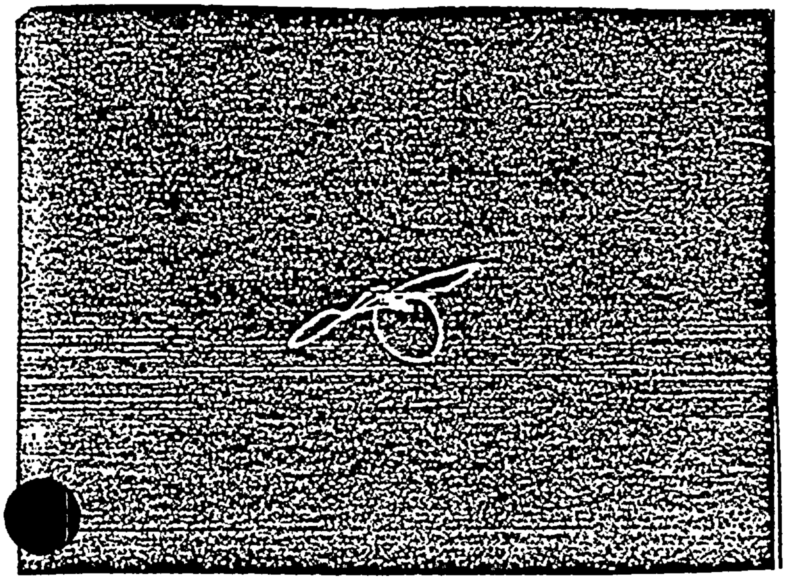
41%

TURKEY POINT #4(FLA) FIG. A-26

S/G-B C.L.

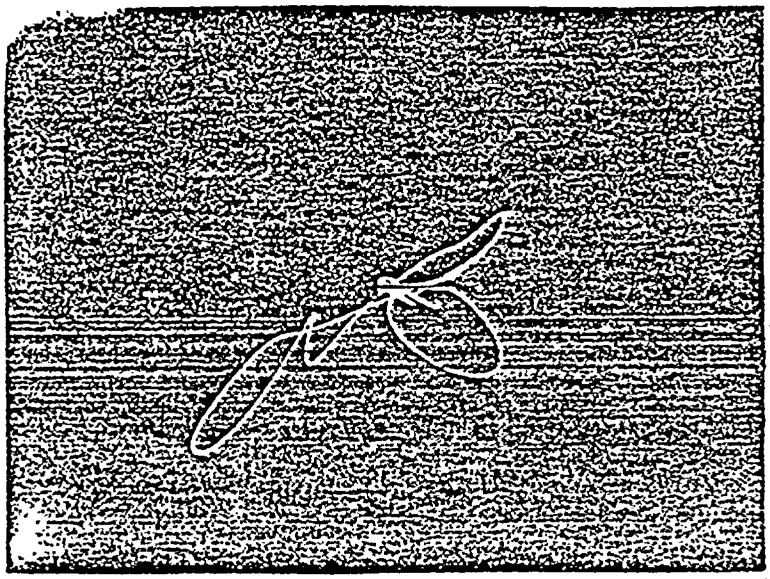
2 Volts/Division

4/79



22%

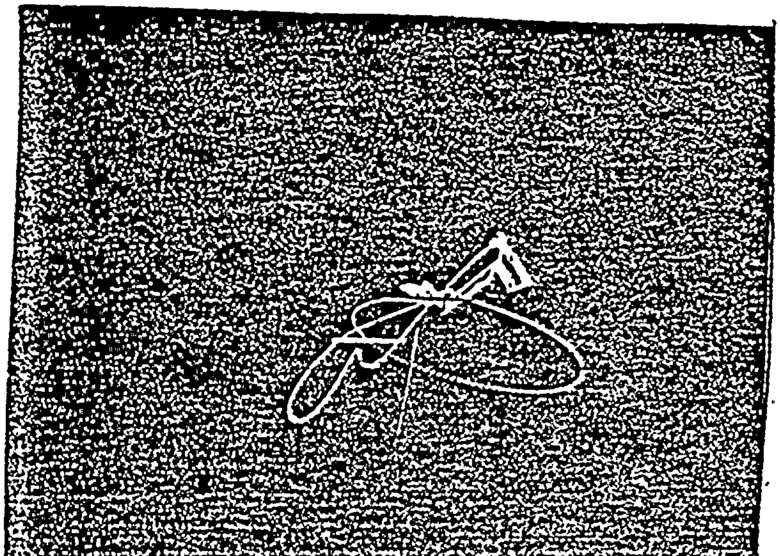
5/80



39%

R10C47
3" ATS

11/80



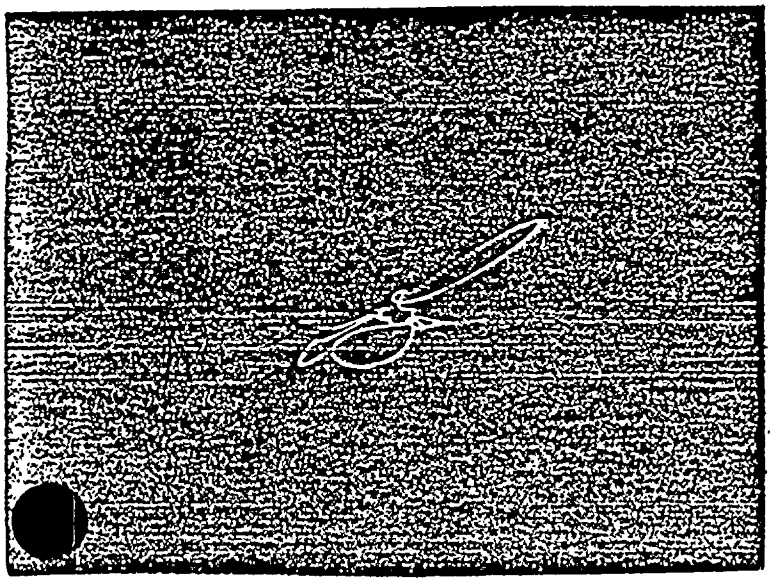
47%

TURKEY POINT #4(FLA)

S/G-B C.L.

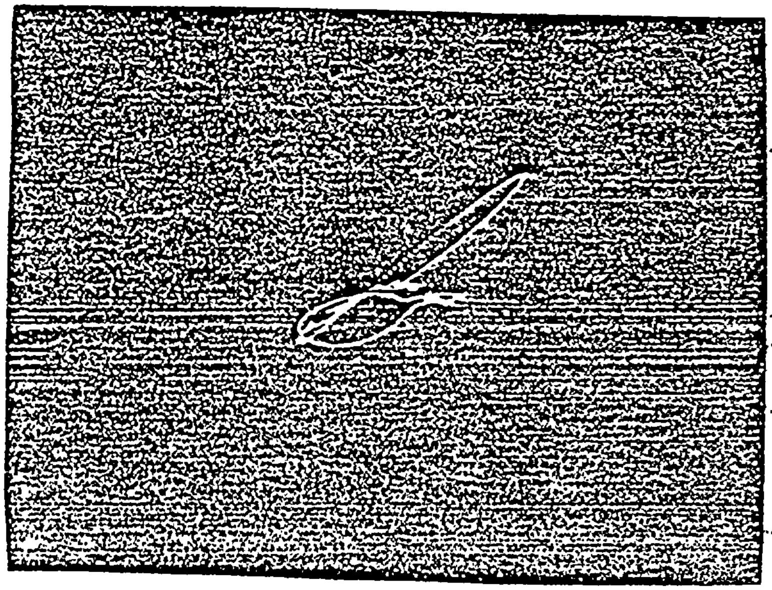
2 Volts/Division

4/79



31%

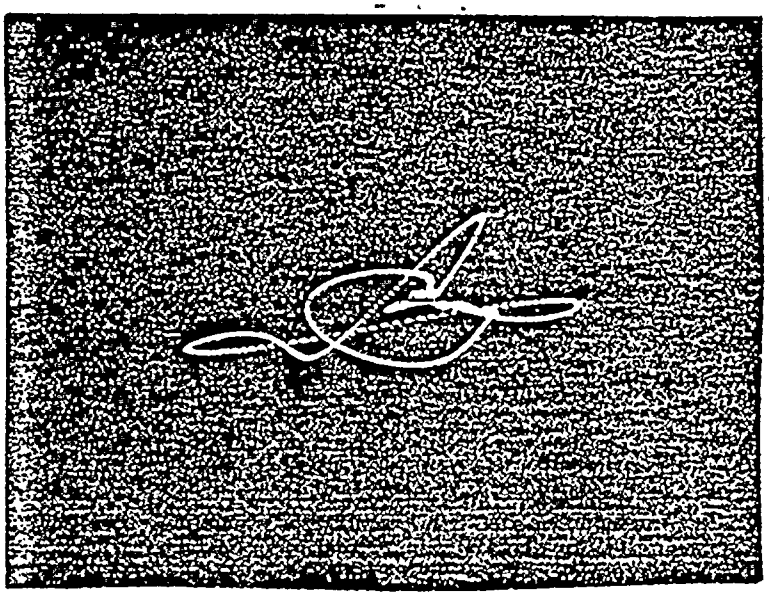
5/80



37%

R7C62
2" ATS

11/80



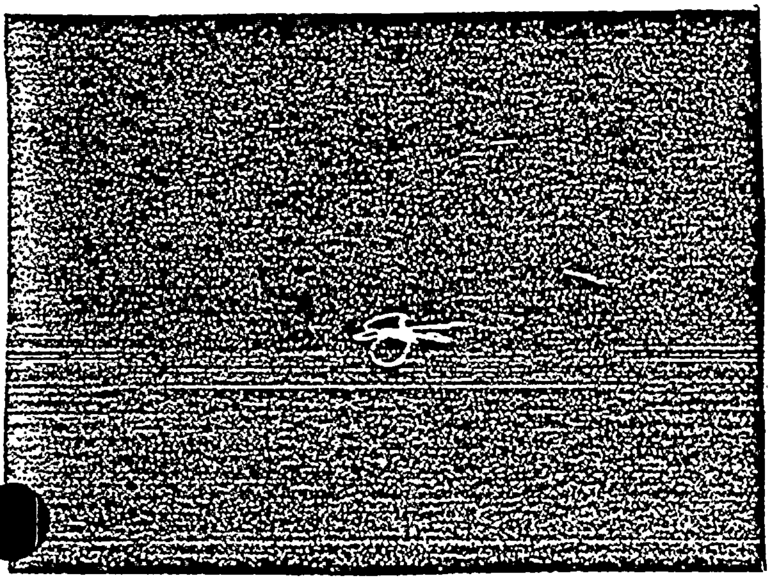
42%

TURKEY POINT #4(FLA) FIG. A-28

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

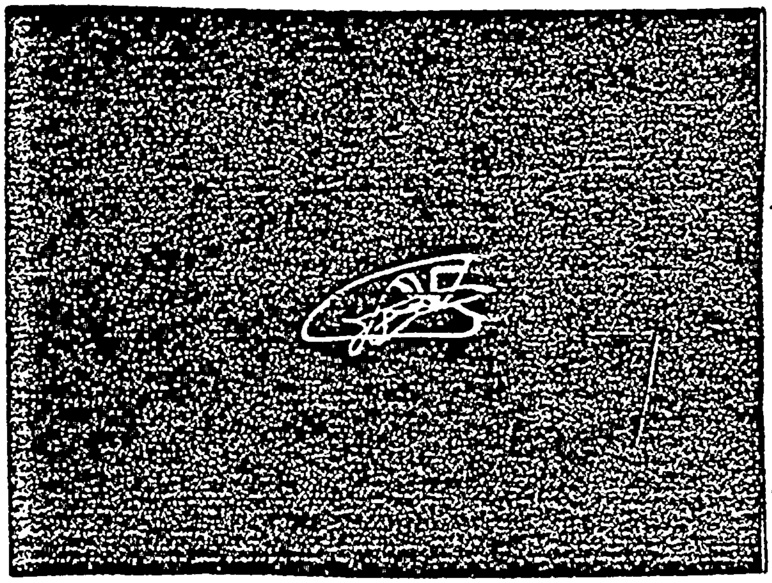
R7C64

2" ATS

5/80

Not Tested

11/80



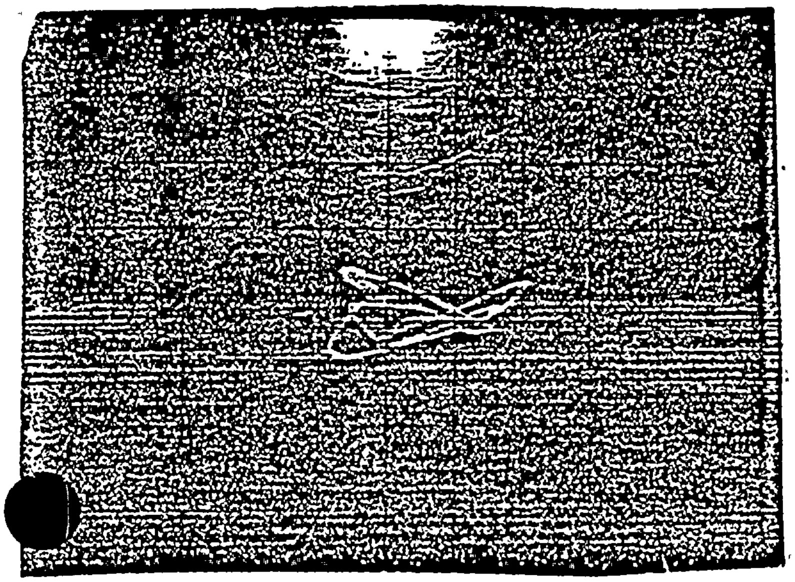
57%

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

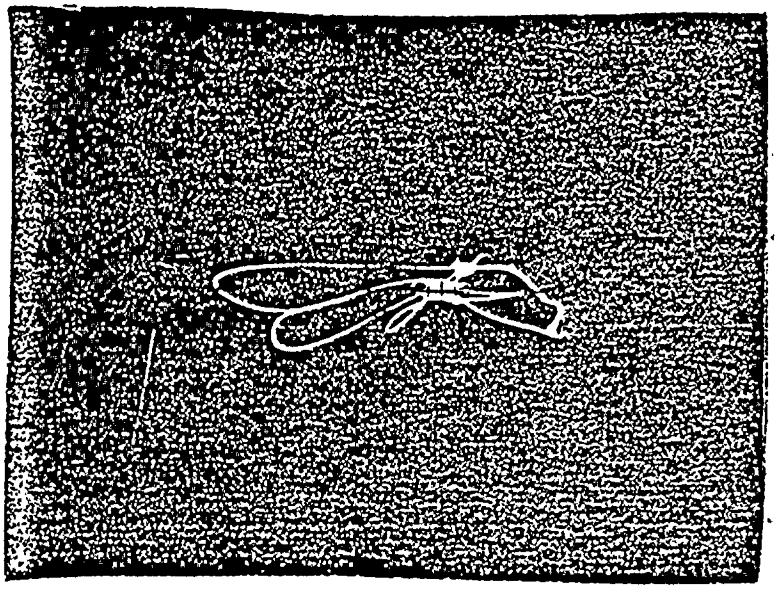
5/80

Not Tested

R7C65

3" ATS

11/80



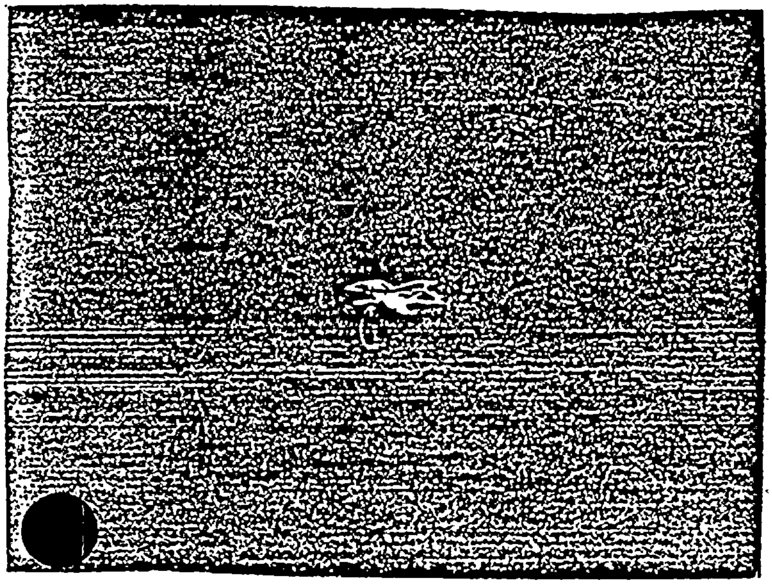
42%

TURKEY POINT #4(FLA)

S/G-B C.L.

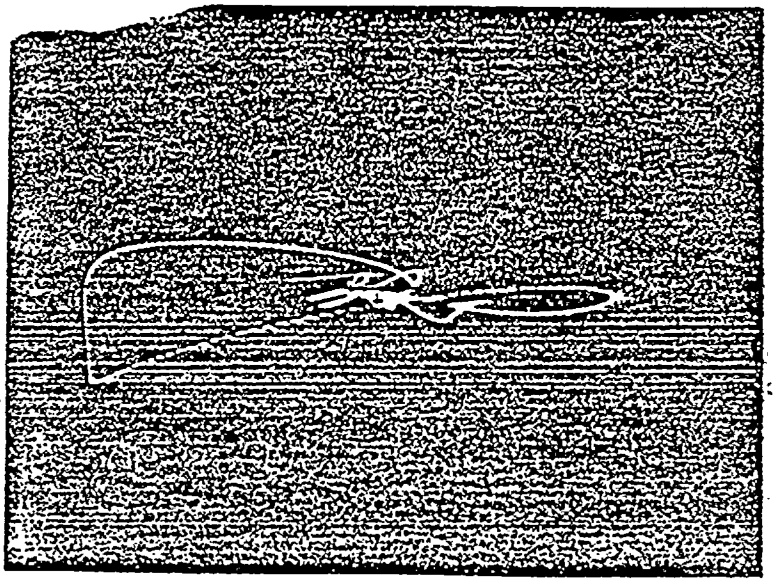
2 Volts/Division

4/79



20%

5/80

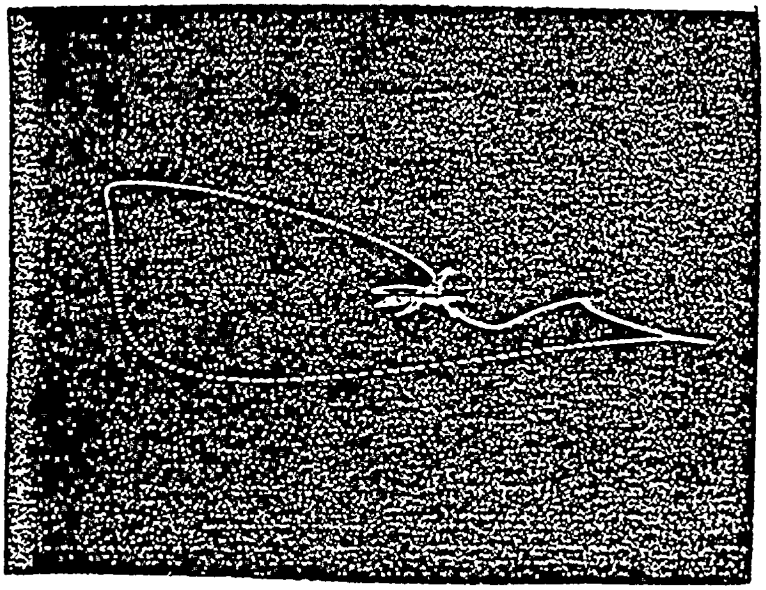


22%

R17C69

3" ATS

11/80



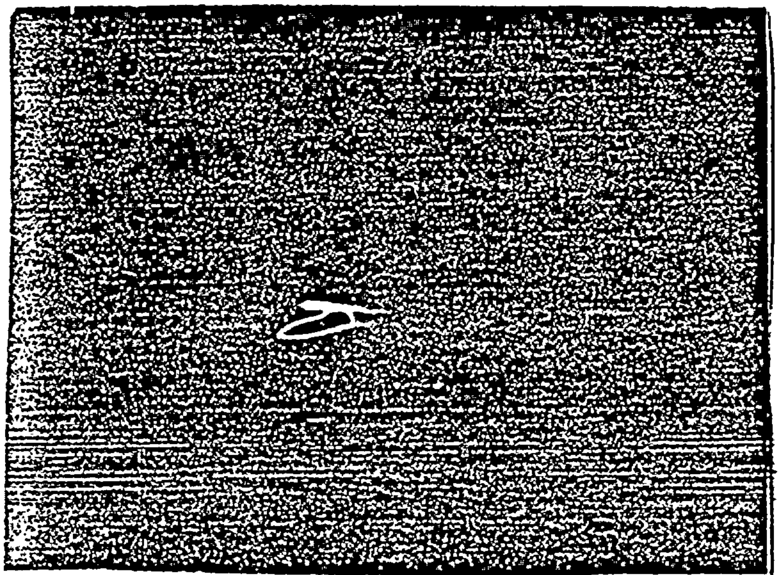
44%

TURKEY POINT #4(FLA)

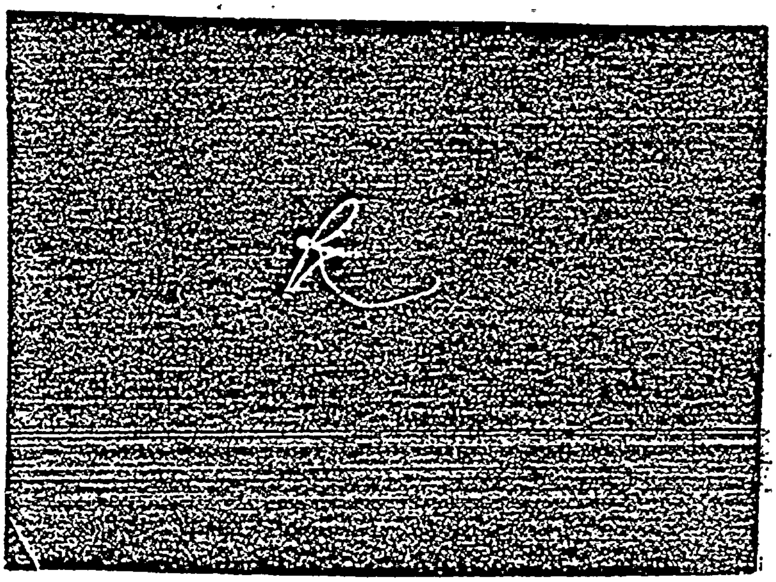
S/G-C H.L.

2 Volts/Division

4/79



11/80



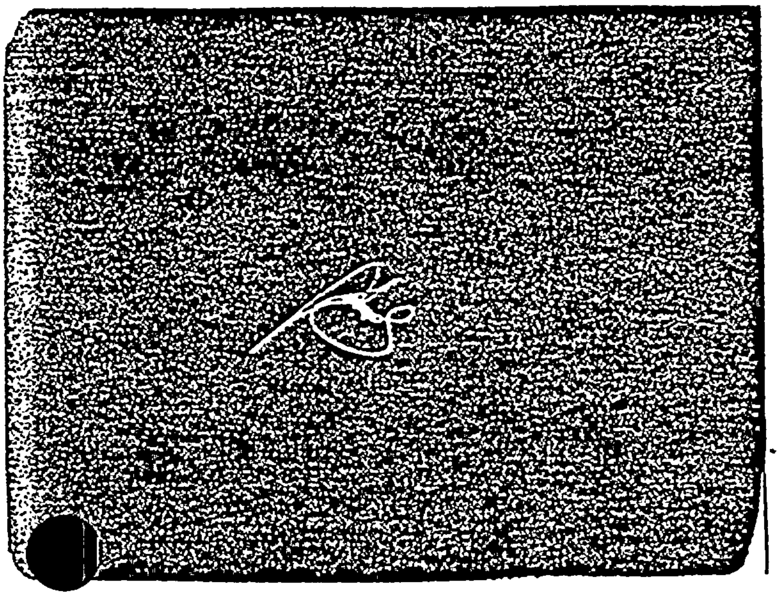
Not Quantified

R44C53

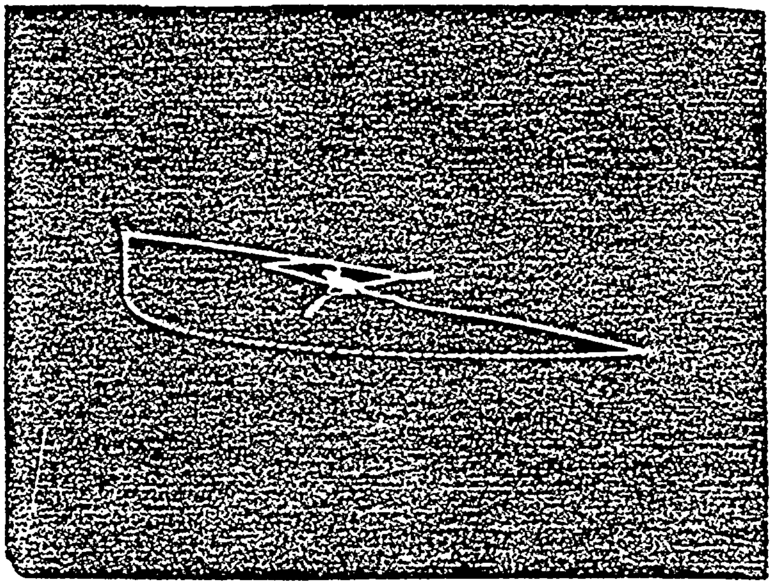
1" ATS

51%

5/75



11/80



36%

R14C53

2" ATS

49%

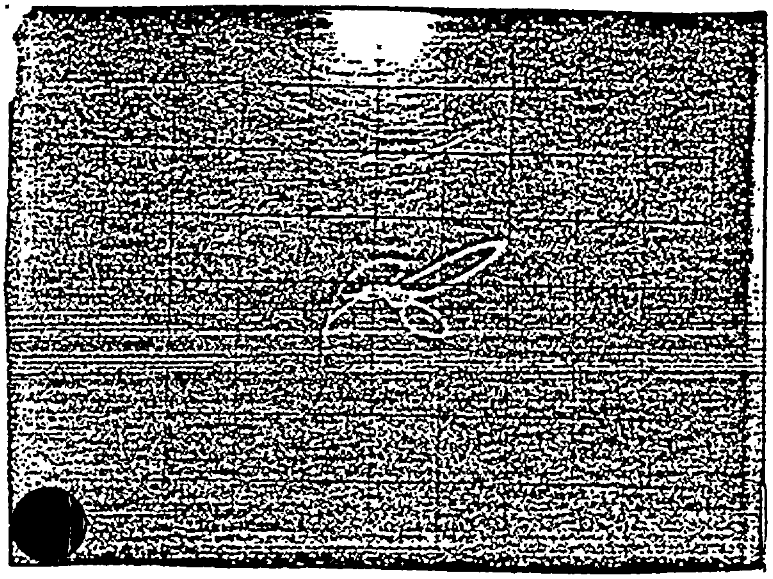
FIG. A-32

TURKEY POINT #4(FLA)

S/G-C C.L.

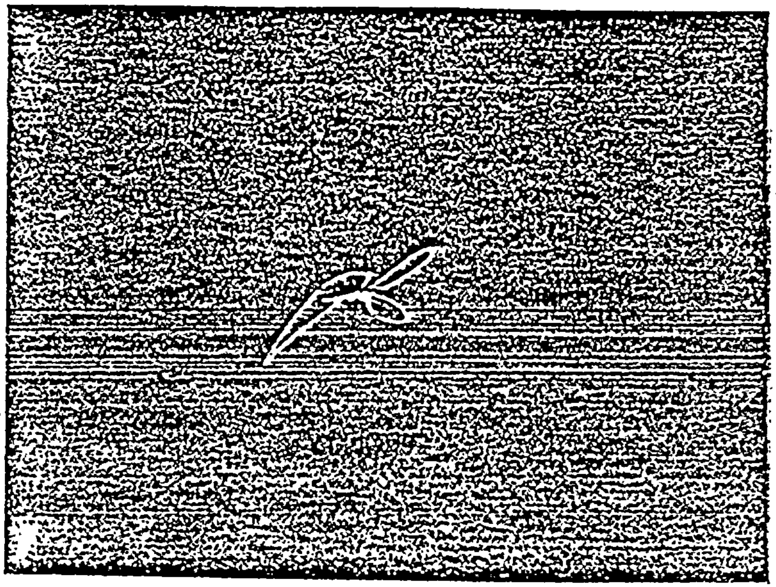
2 Volts/Division

4/79



31%

5/80

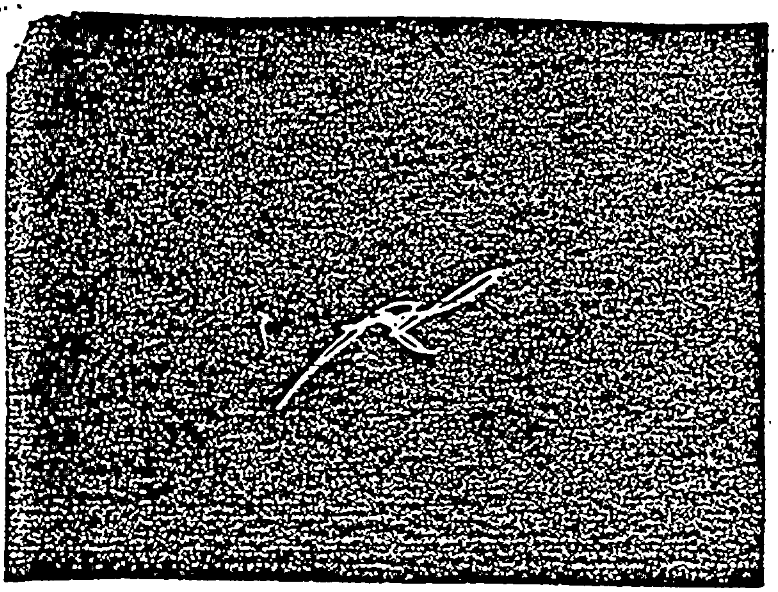


31%

R10C46

2" ATS

11/80



44%

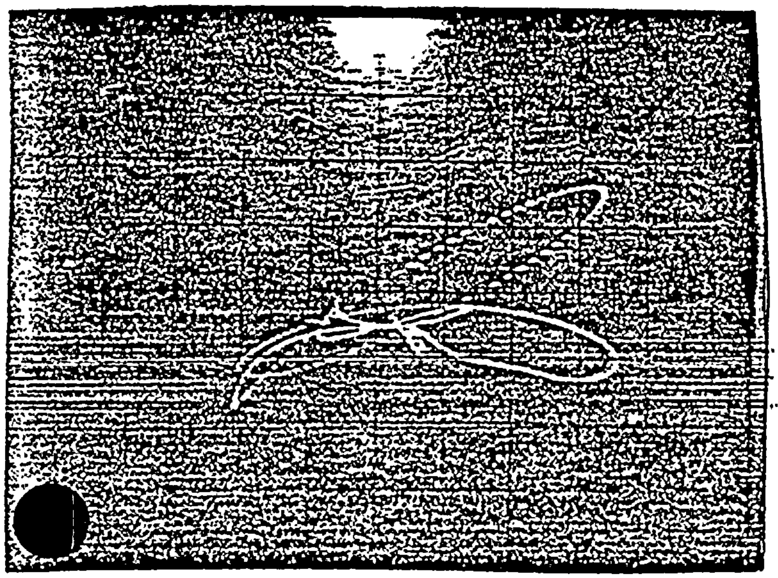
FIG. A-33

TURKEY POINT #4 (FLA)

S/G-C C.L.

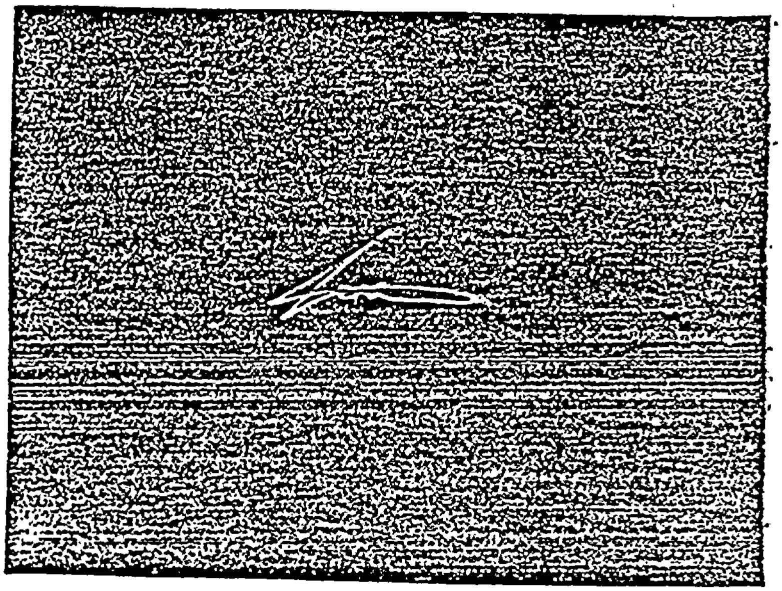
2 Volts/Division

4/79



30%

5/80

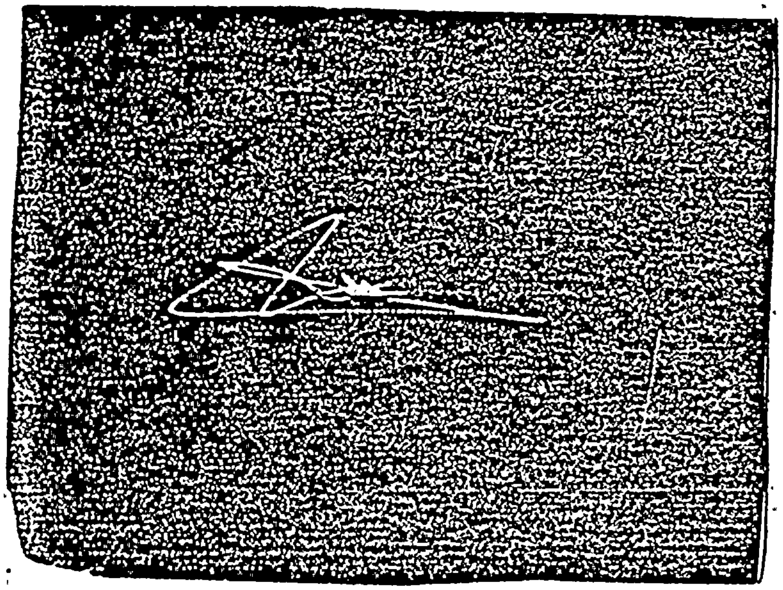


33%

R5C58

TTS

11/80



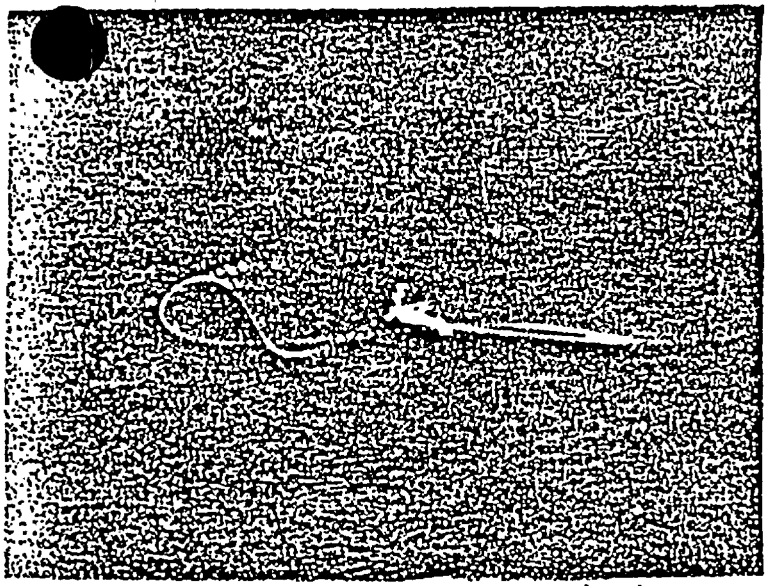
44%

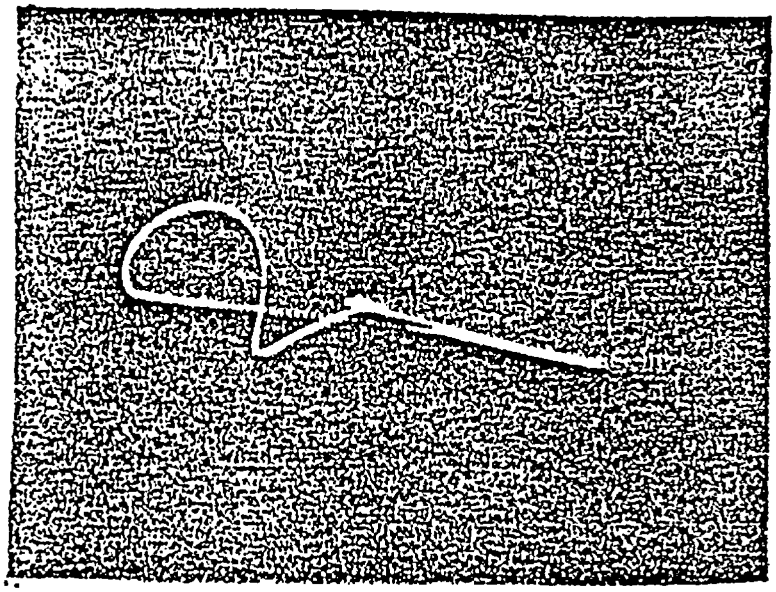
[illegible]

FIG. A-1[illegible]

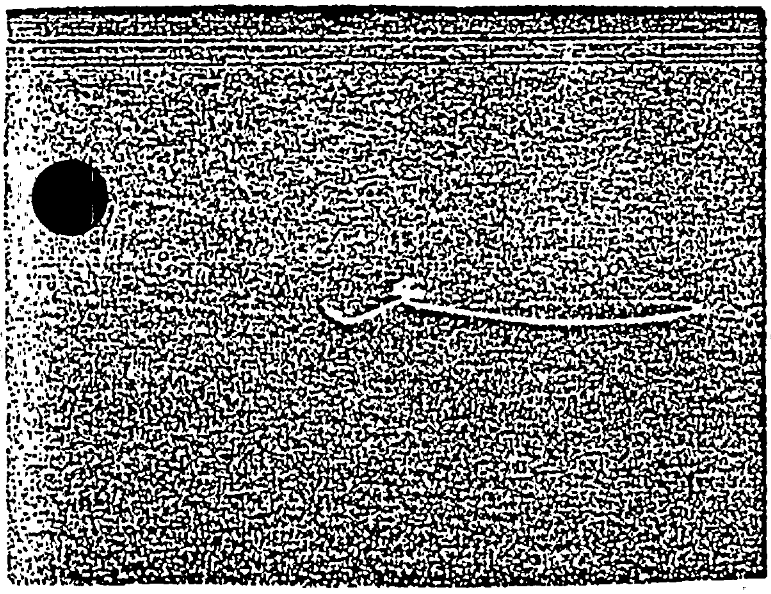
S/G A H.L.

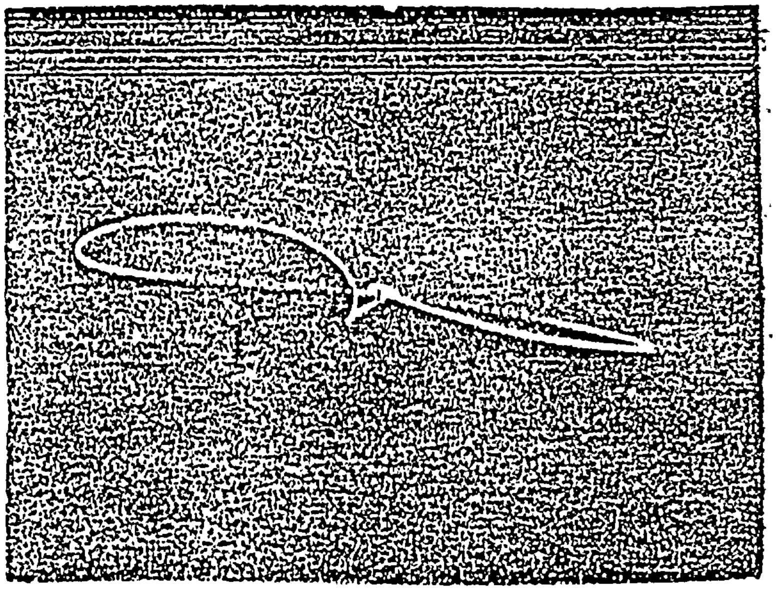
4/79 2 VOLTS/DIVISION 11/80



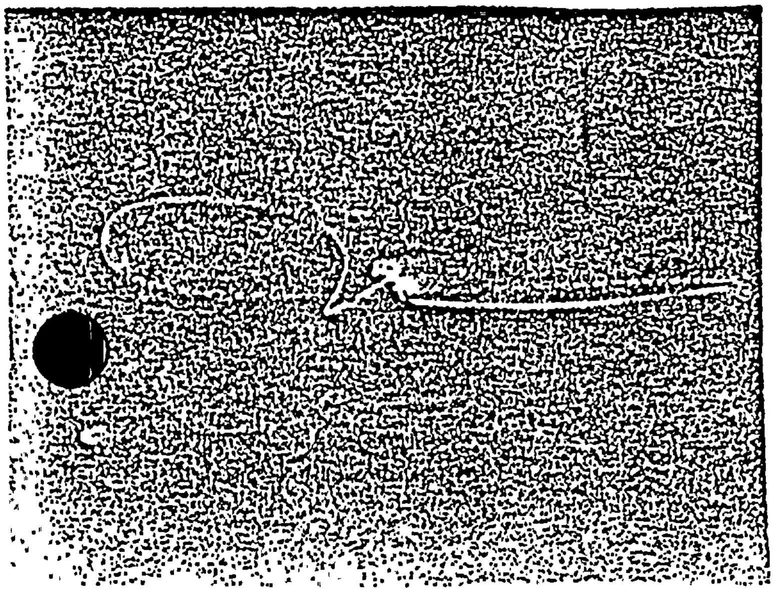


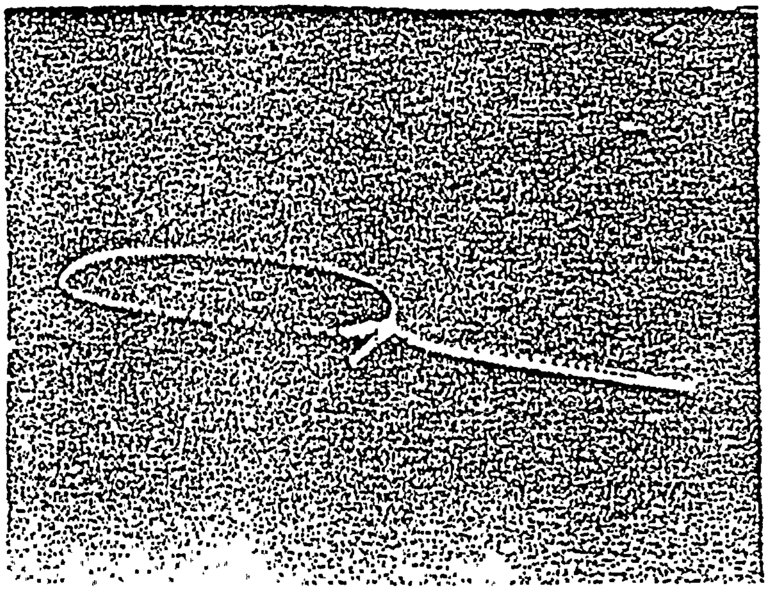
Not Quantified R6C75 6[illegible]% TTS





Not Quantified R11C22 58% TTS



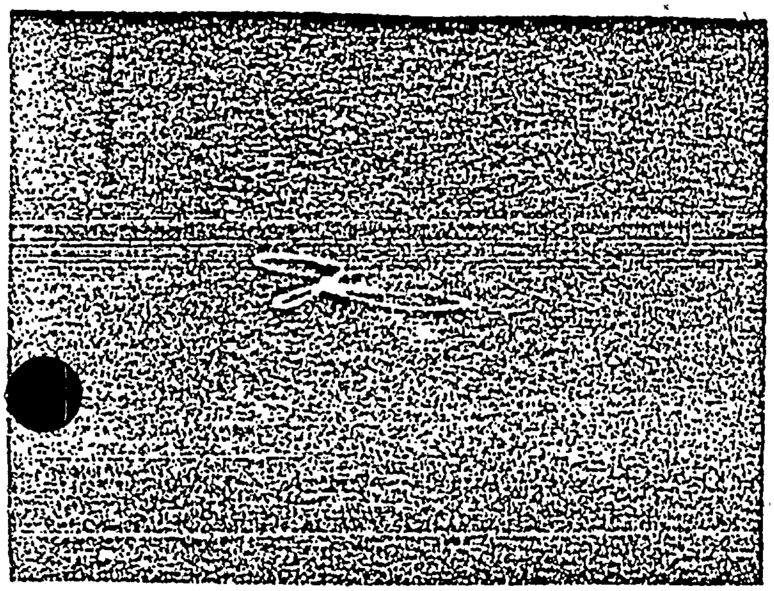


TURKEY POINT #4 (FLA)

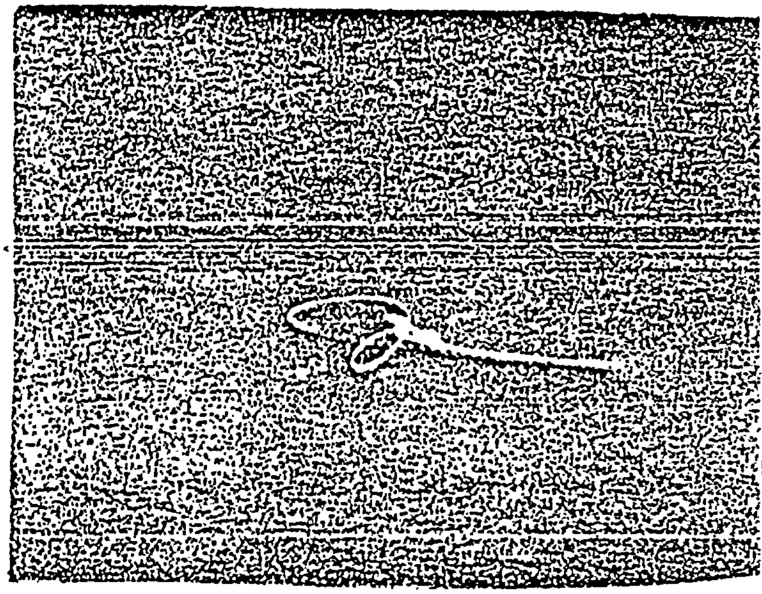
S/G B H.L.
2 VOLTS/DIVISION

4/79

11/80



Not Quantified R9C81



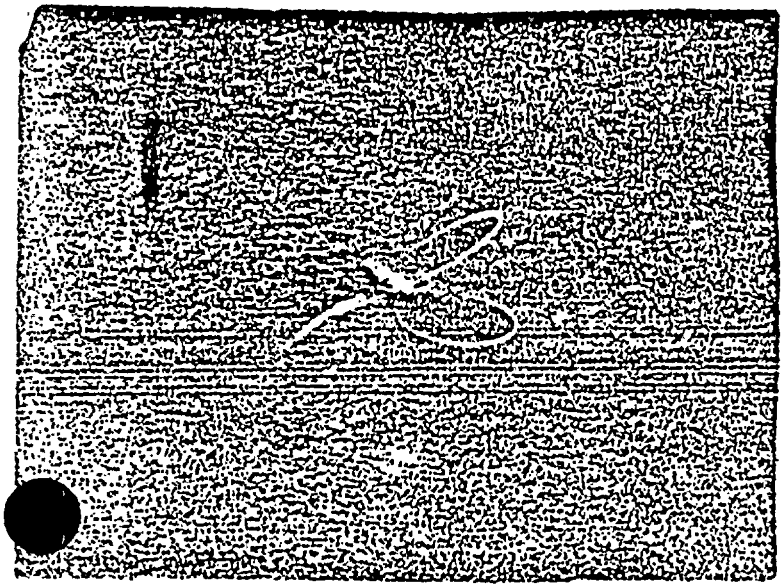
51% 1" ATS

TURKEY POINT #4(FLA)

S/G-B C.L.

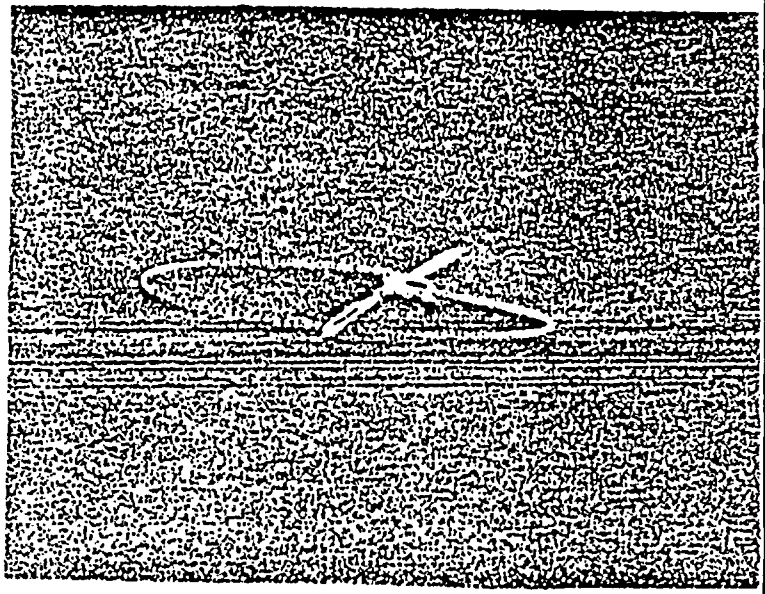
2 Volts/Division

4/79



59%

5/80

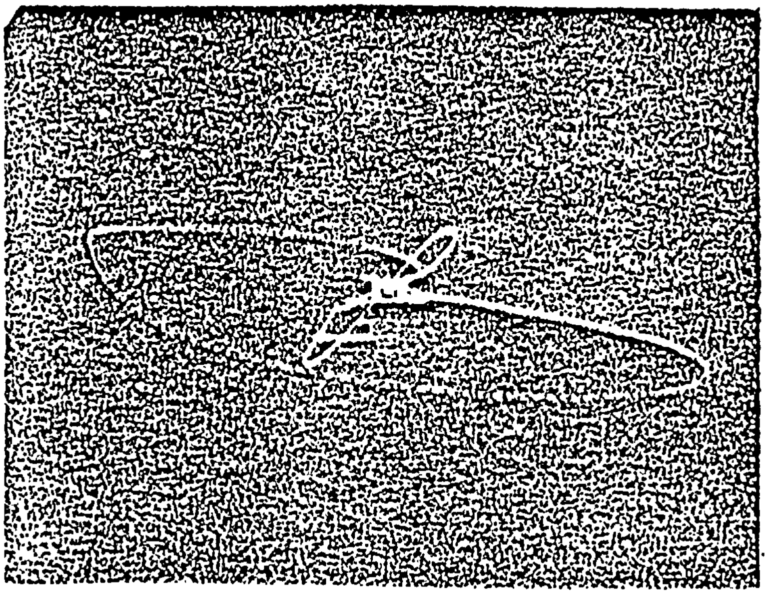


55%

R14C29

2" ATS

11/80



46%

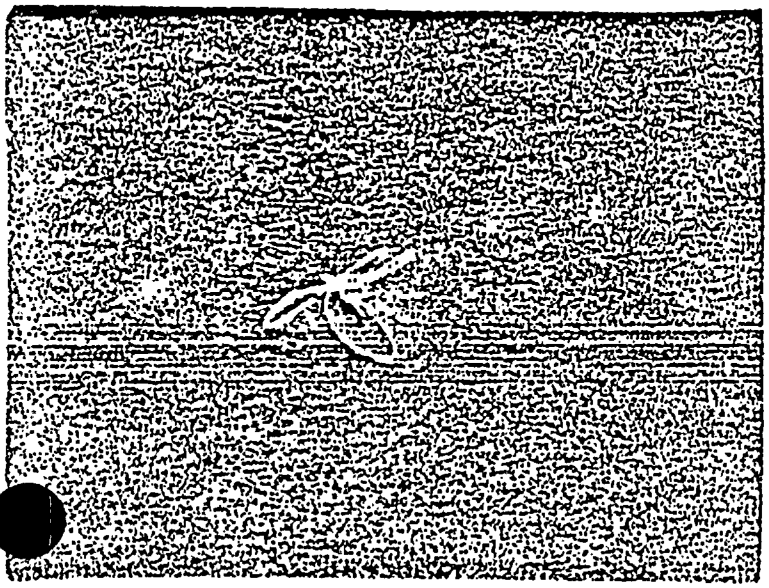
FIG. A 15

TURKEY POINT #4(U-LA)

S/G-B C.L.

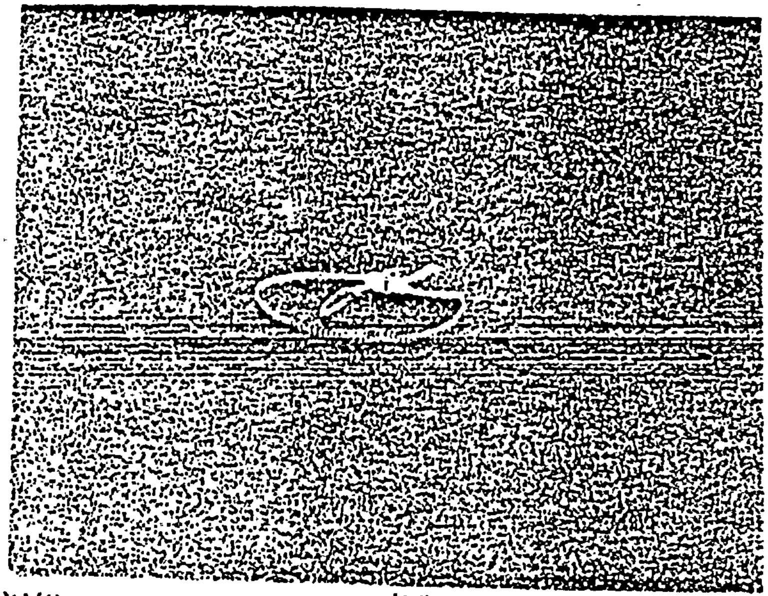
2 Volts/Division

4/79



55%

5/80

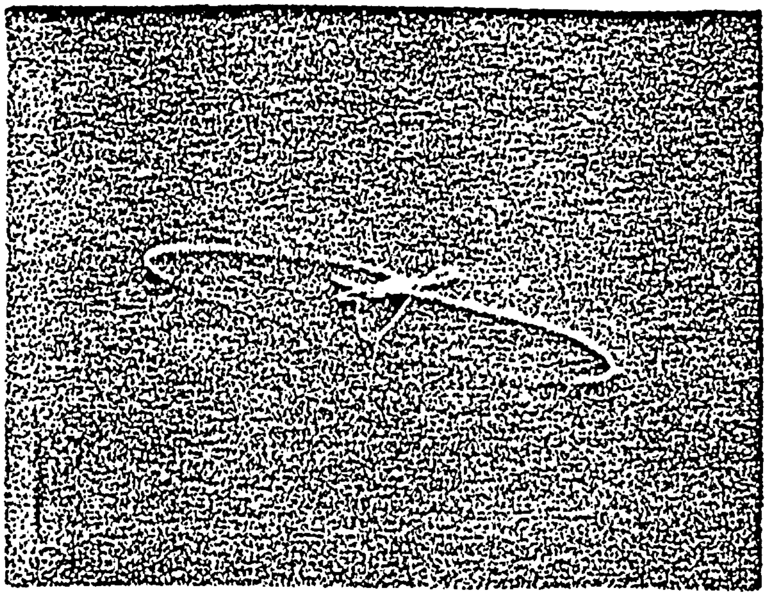


55%

R12C50

2" ATS

11/80



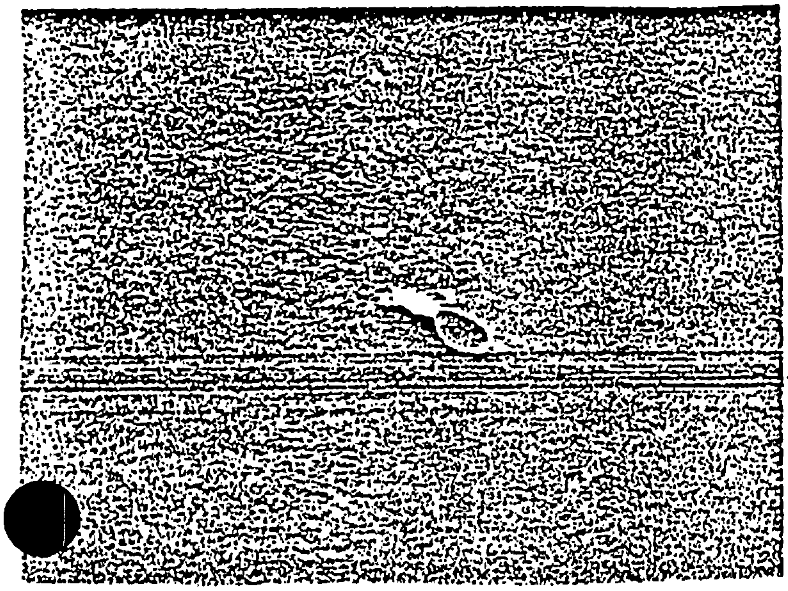
55%

TURKEY POINT #4(11A)

S/G B C.L.

2 Volts/Division

4/79



Not Quantified

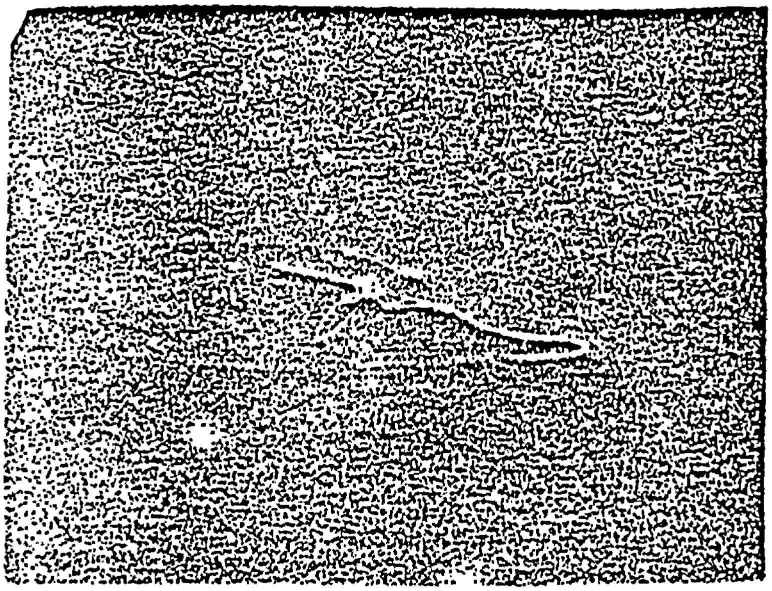
5/80

Not Tested

R23C39

.2" ATS

11/80



45%

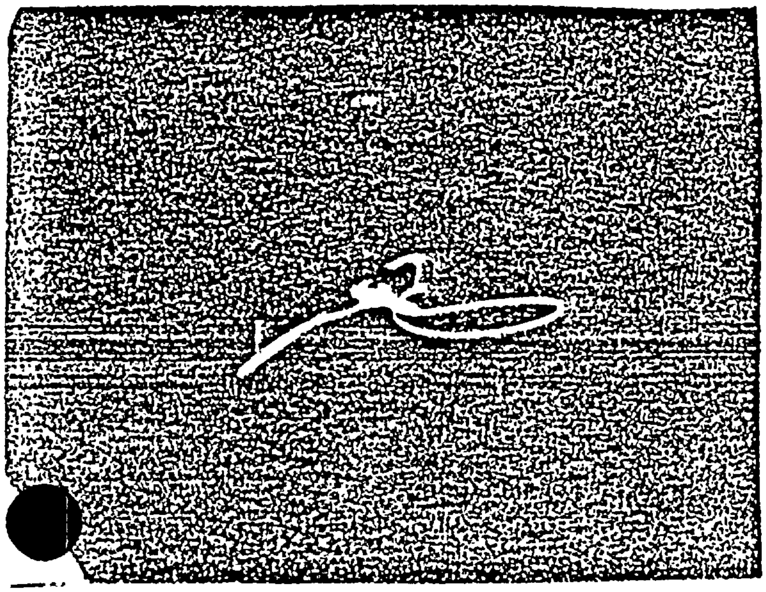
FIG. 5 17

TURKEY POINT #4 (FLA)

S/G-B C.L.

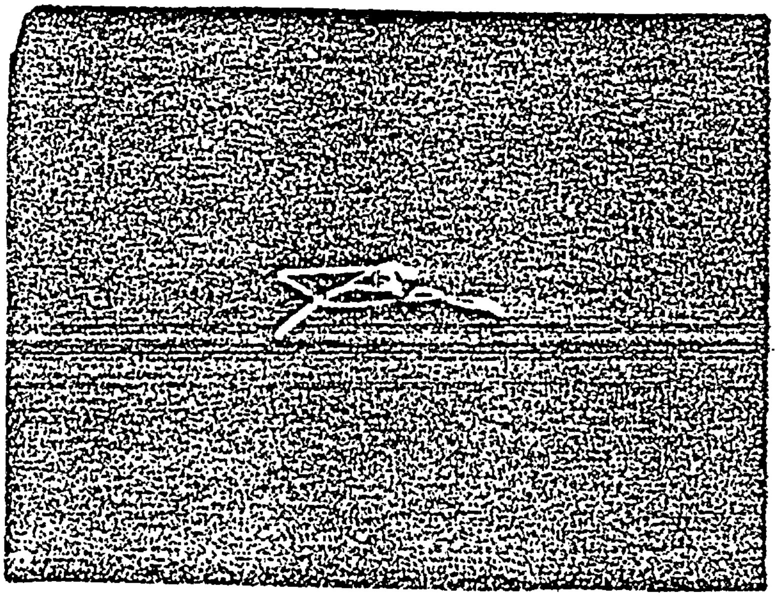
2 Volts/Division

4/79



38%

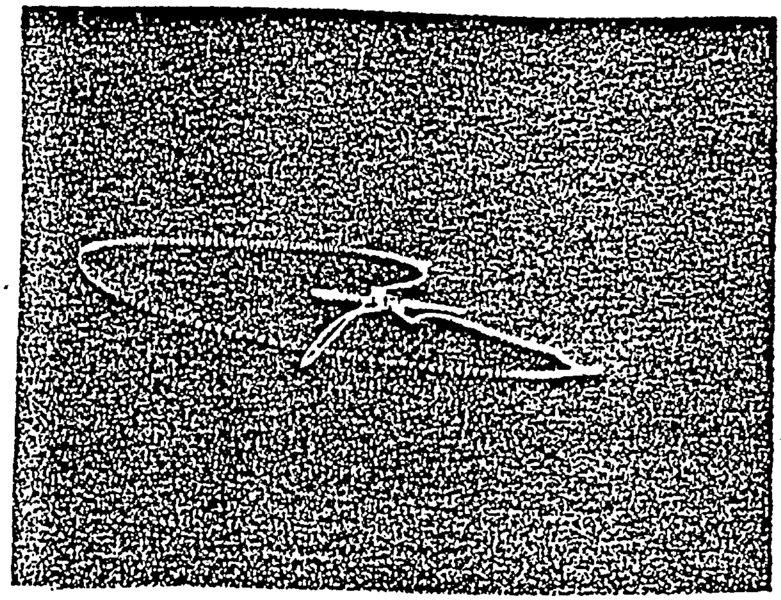
5/80



31 %

R24C39

1" ATS



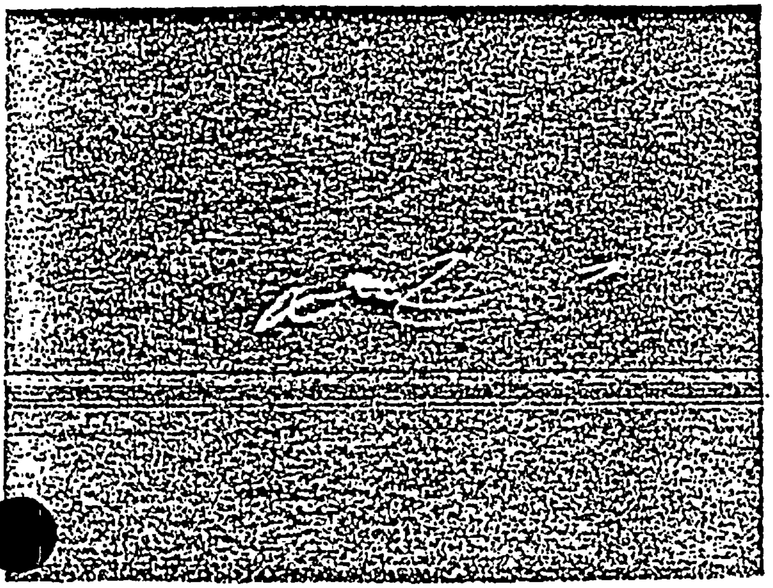
44%

TURKEY POINT #4(FLA)

S/G-B C.L.

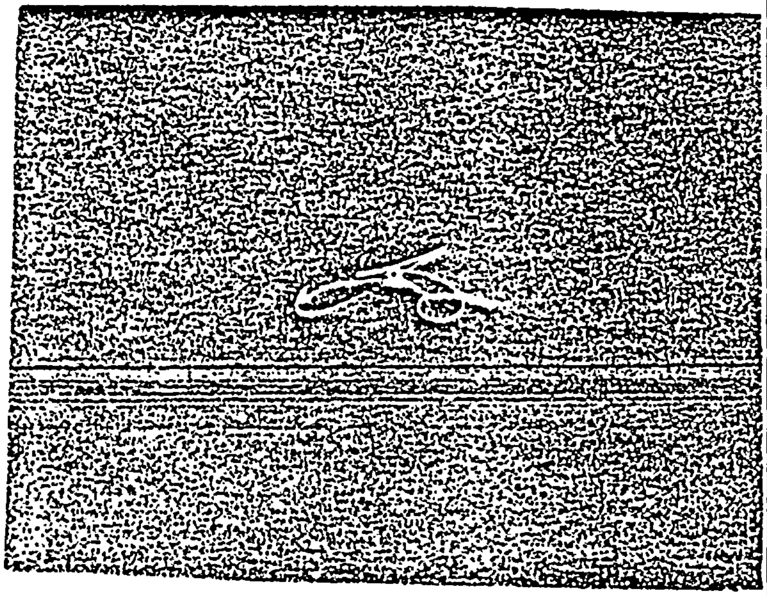
2 Volts/Division

4/79



< 20%

5/80

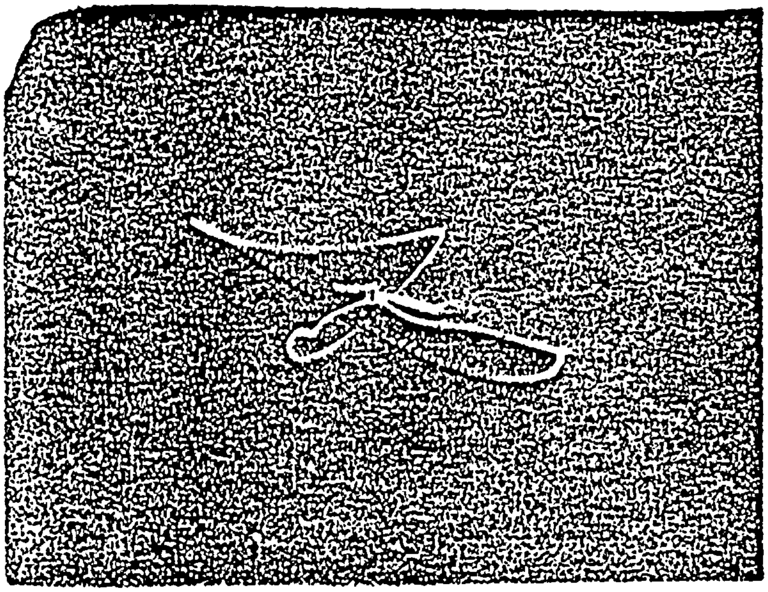


24%

R24C40

½" ATS

11/80



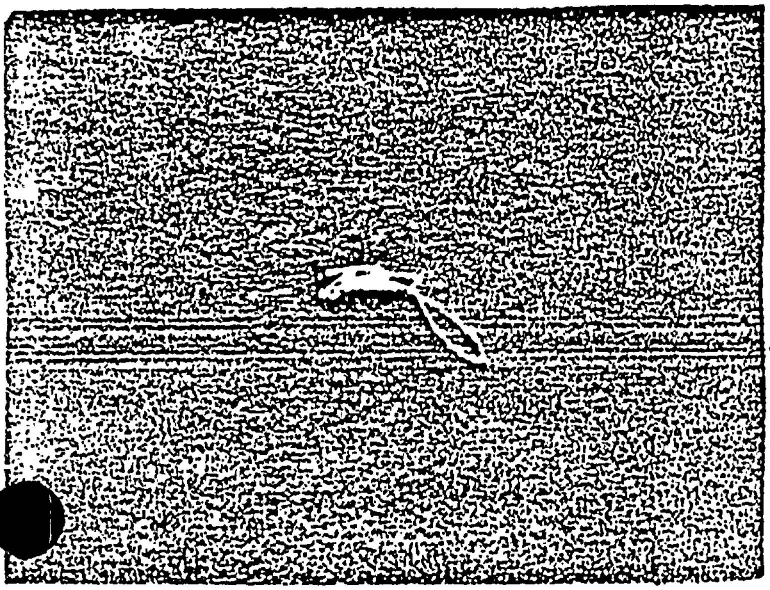
41%

TURKEY POINT #4(FLA)

S/G-B C.L.

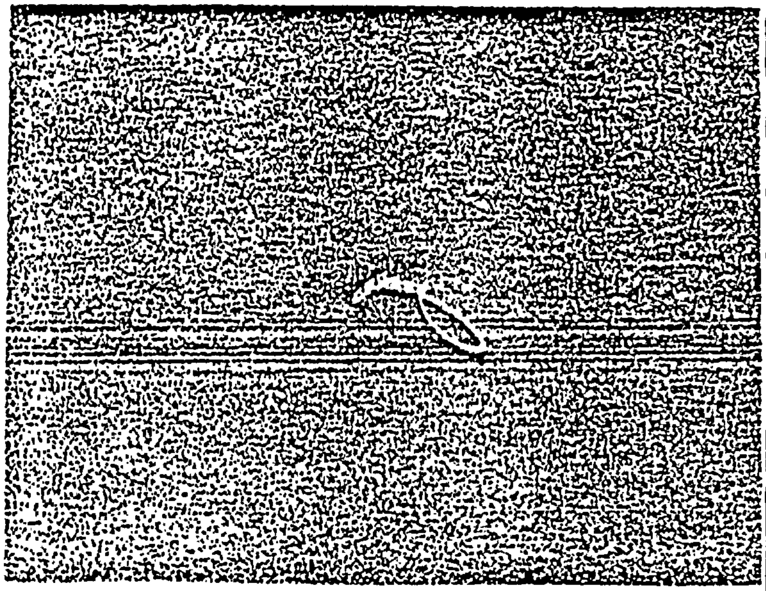
2 Volts/Division

4/79



24%

5/80

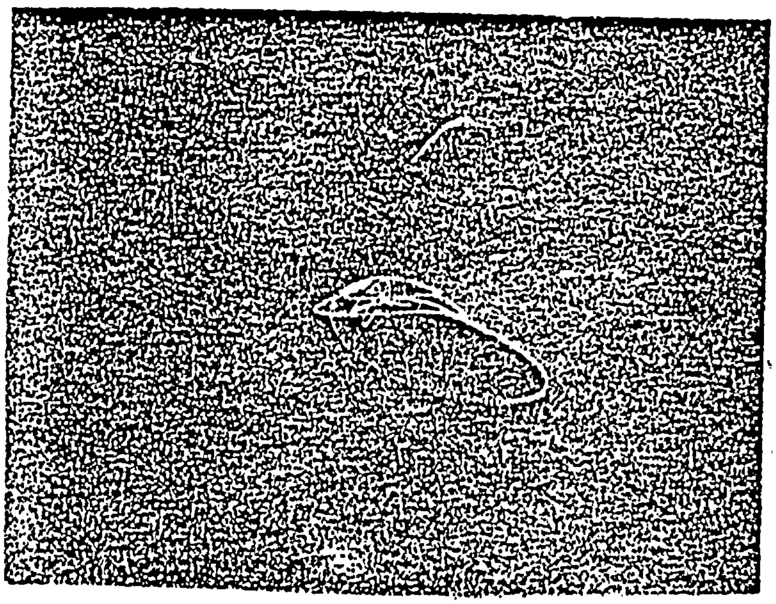


36%

R11C44

2" ATS

11/80



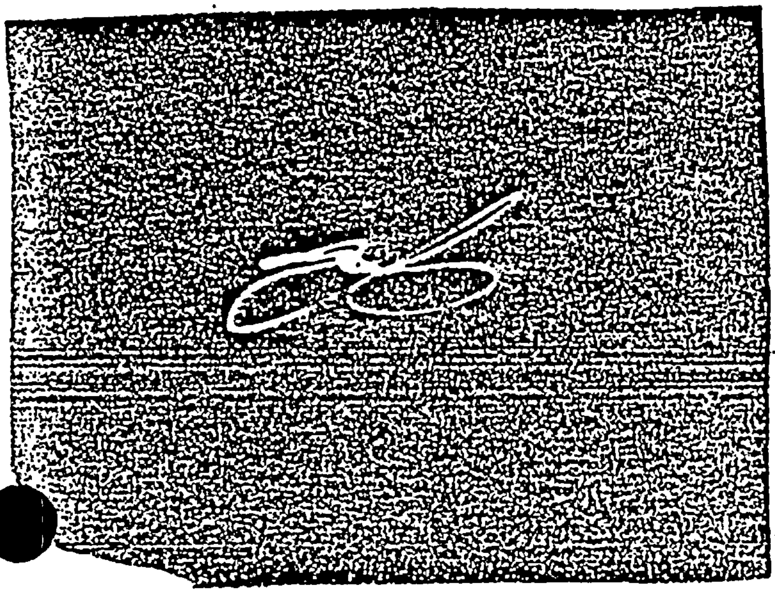
55%

TURKEY POINT #4(FLA)

S/G-B C.L.

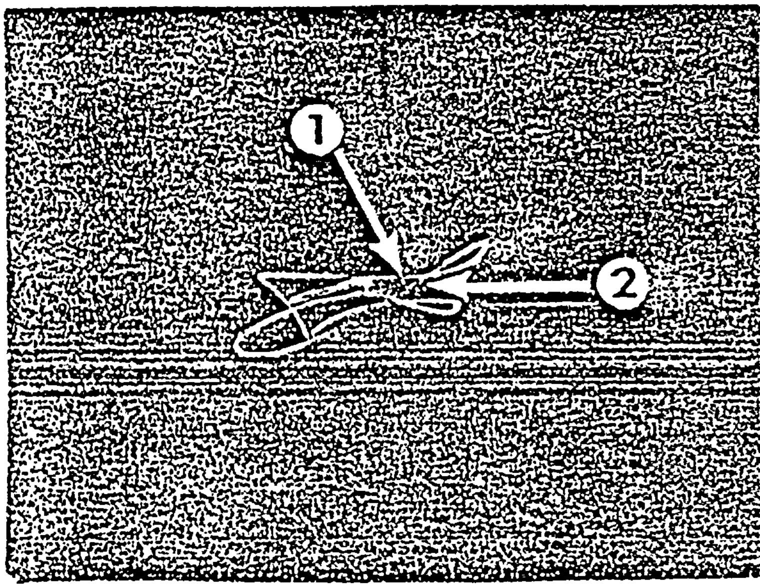
2 Volts/Division

4/79



28%

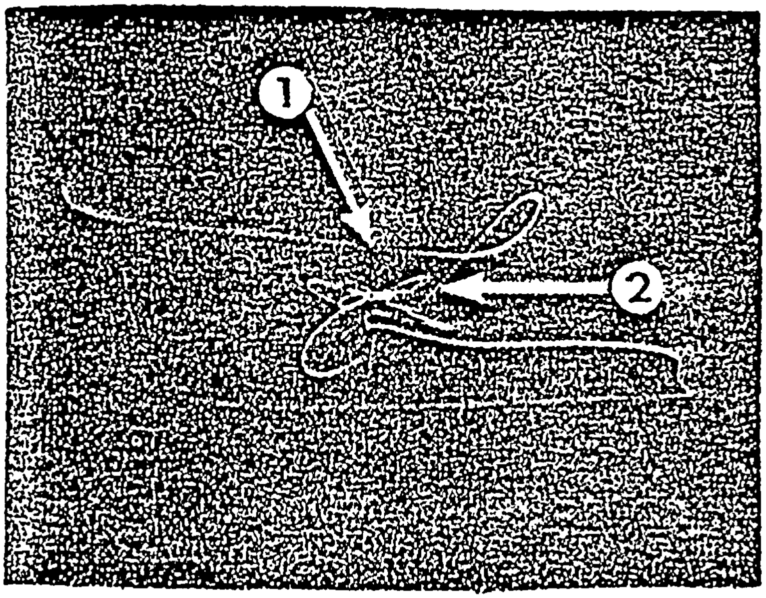
5/80



28%

R22C44
1" ATS

11/80



45%

TURKEY POINT #4(FLA)

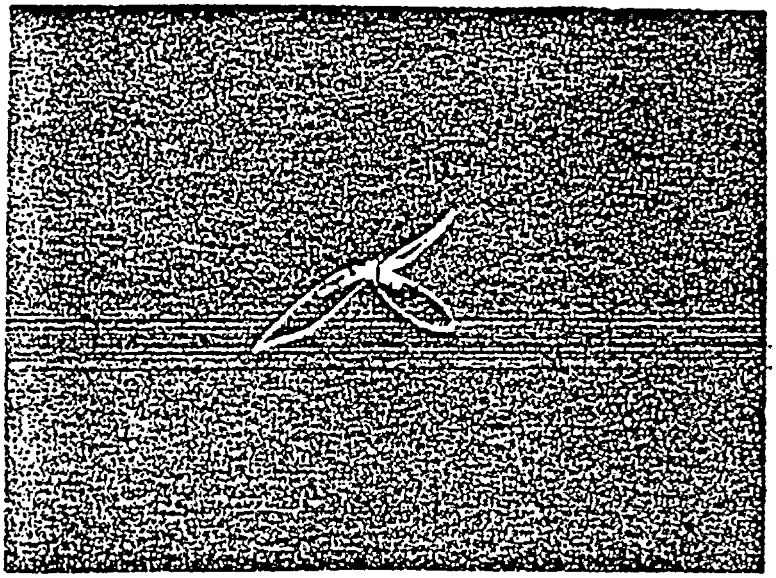
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

5/80

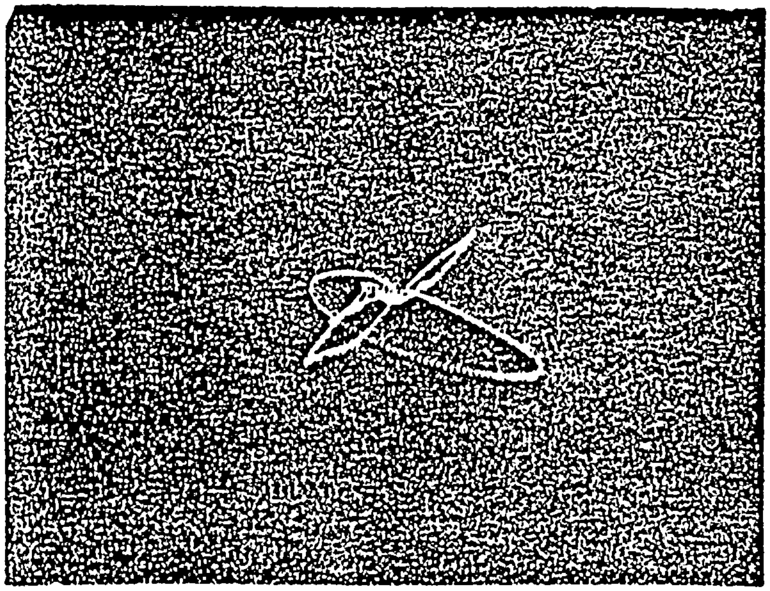


R10C46

2" ATS

37%

11/80



45%

FIG. A 22

TURKEY POINT #4(FLA)

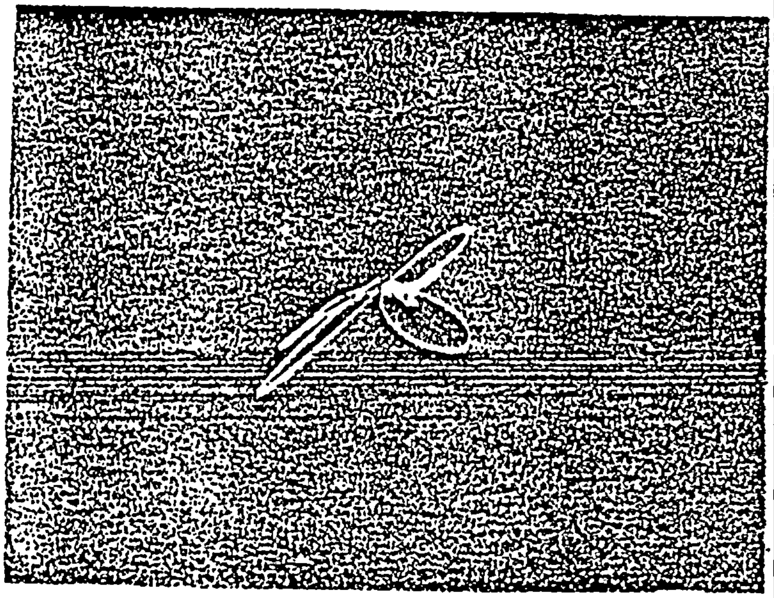
S/G B C.L.

2 Volts/Division

4/79

Not Tested

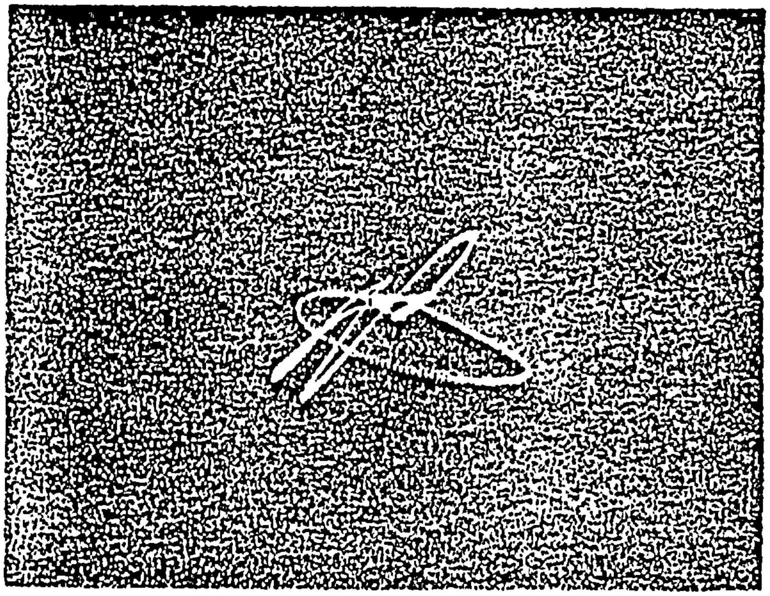
5/80



R11C46 39%

2" ATS

11/80



45%

FIG. A 25

TURKEY POINT #4(FLA)

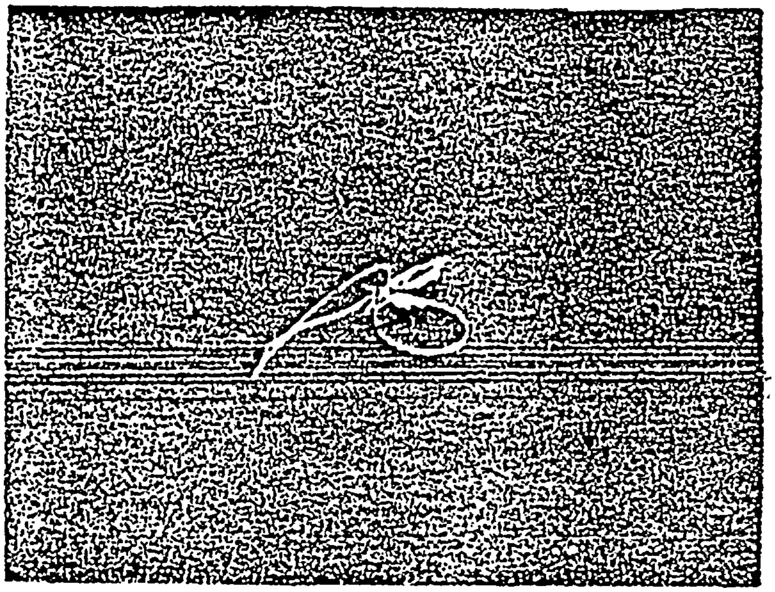
S/G B C.L.

2 Volts/Division

4/79

NOT TESTED

5/80

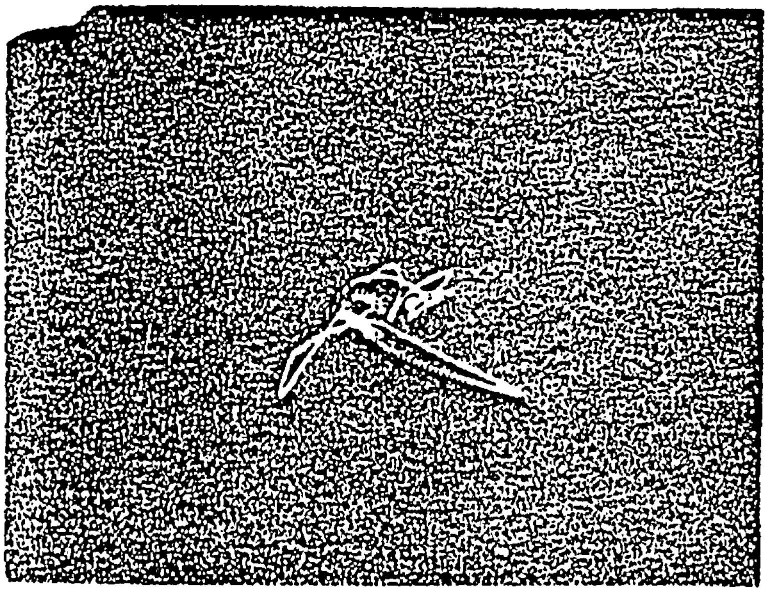


R13C46

3" ATS

33%

11/80



51%

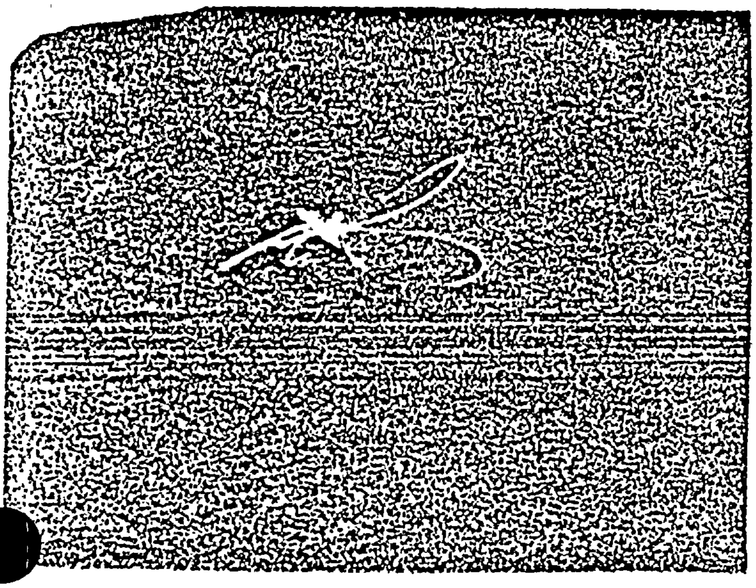
FIG. A 24

TURKEY POINT #4(14A)

S/G-B C.L.

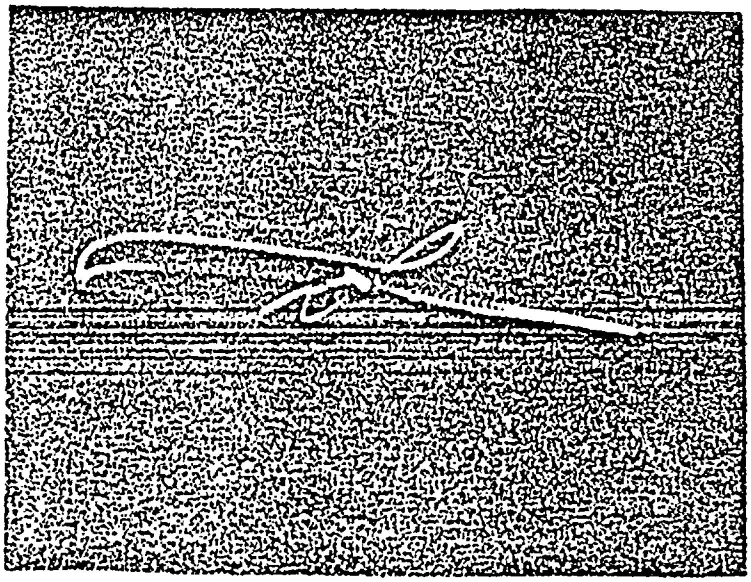
2 Volts/Division

4/79



32%

5/80

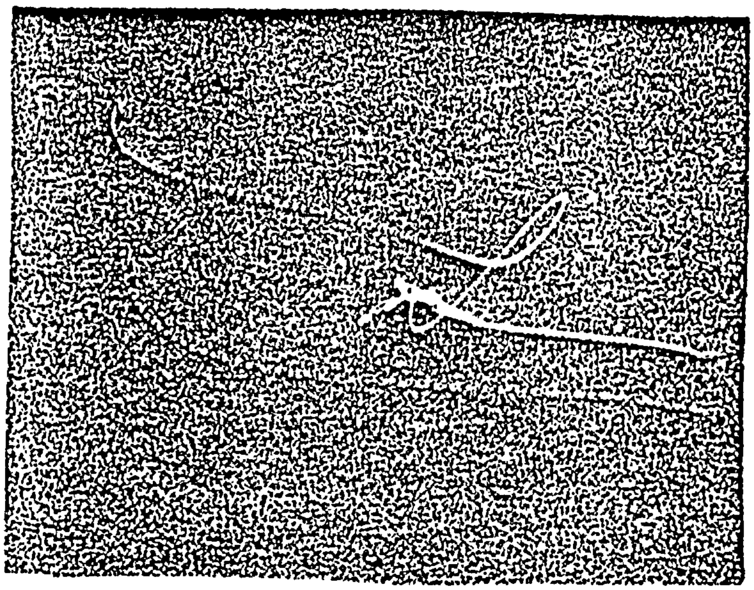


32%

R22C46

½" ATS

11/80



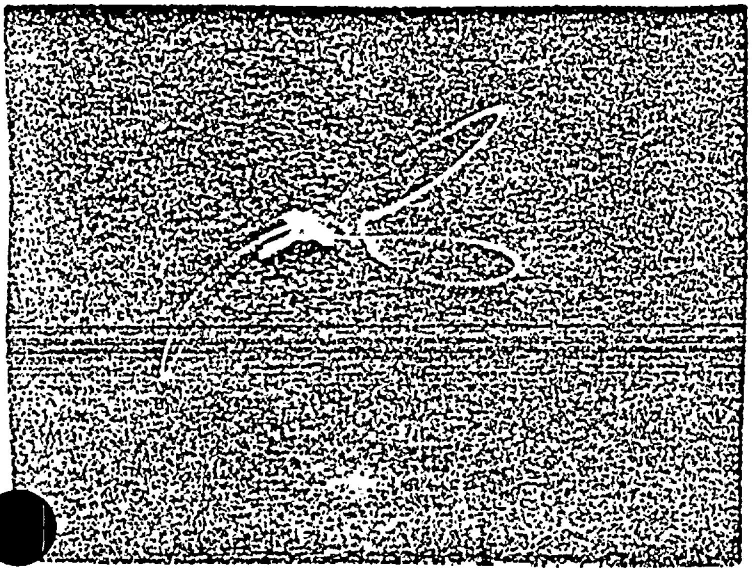
49%

TURKEY POINT #4(FLA)

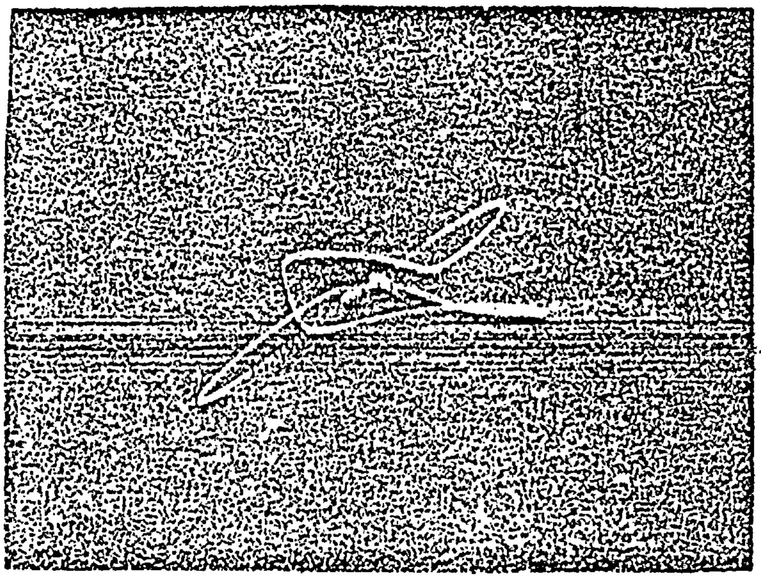
S/G-B C.L.

2 Volts/Division

4/79



5/80



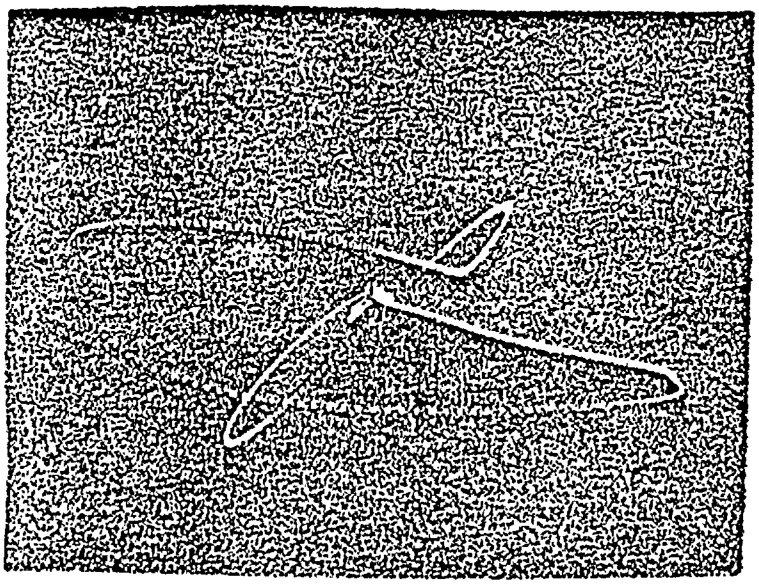
35%

R23C46

52%

1" ATS

11/80



41%

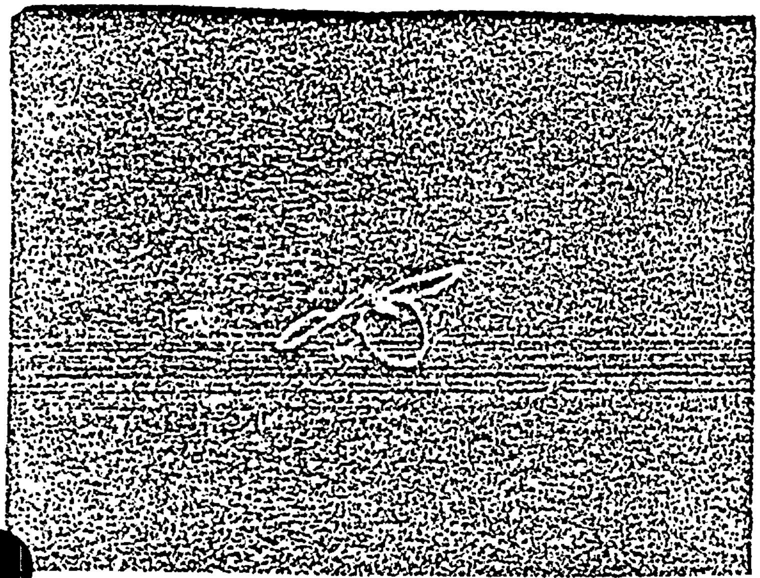
TURKEY POINT #4(FLA)

FIG. A-26

S/G-B C.L.

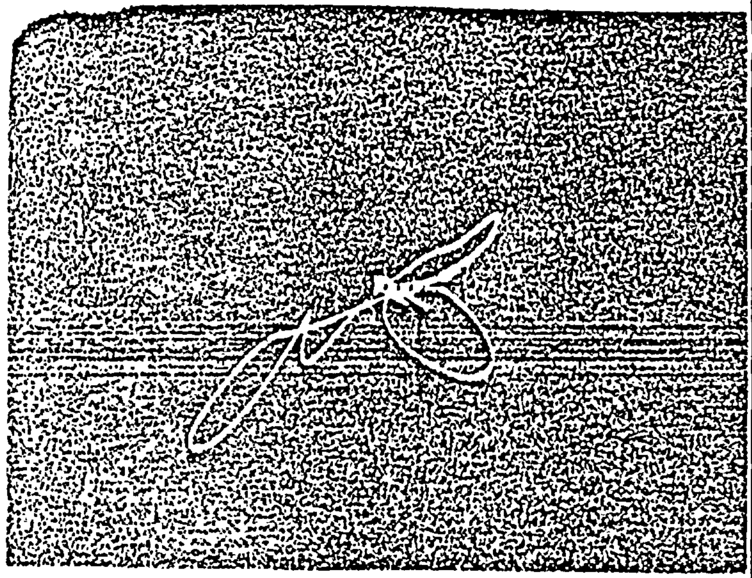
2 Volts/Division

4/79



22%

5/80

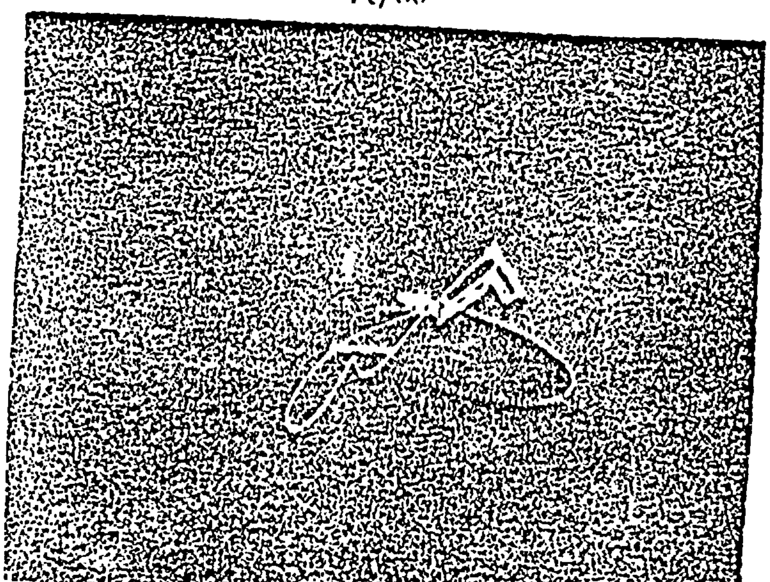


39%

R10C47

3" ATS

11/80



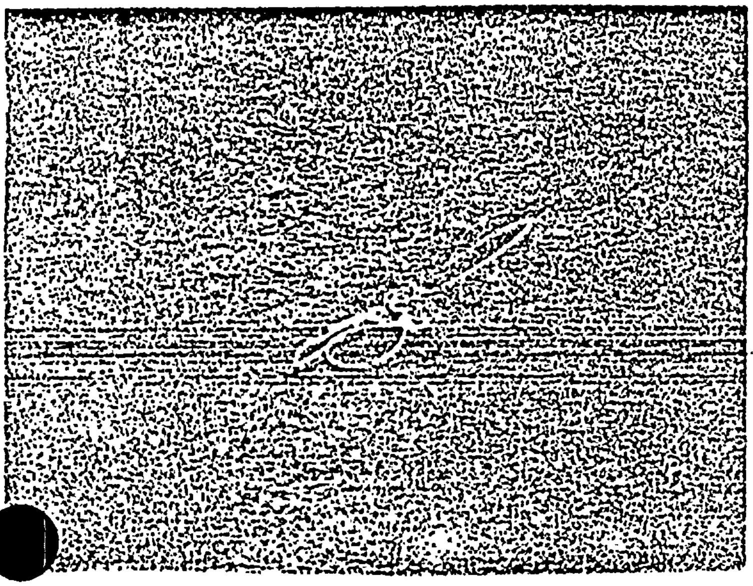
47%

TURKEY POINT #4(FLA)

S/G-B C.L.

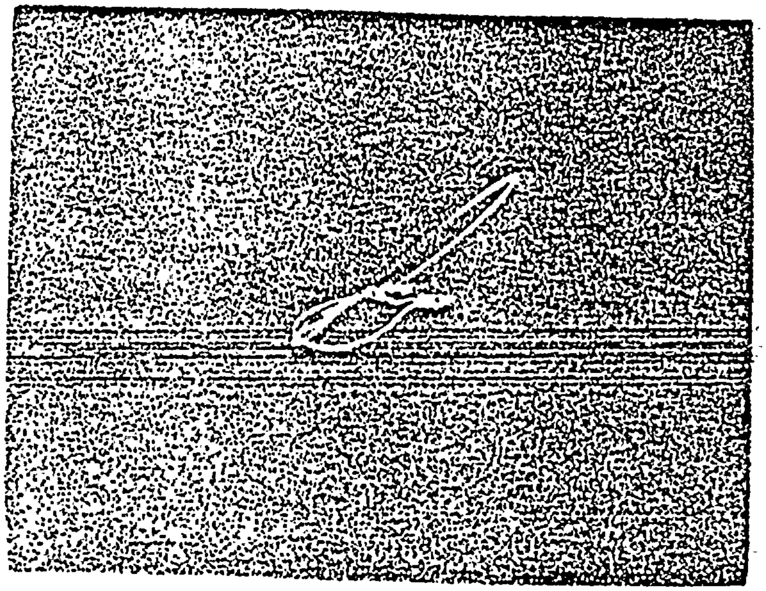
2 Volts/Division

4/79



31%

5/80

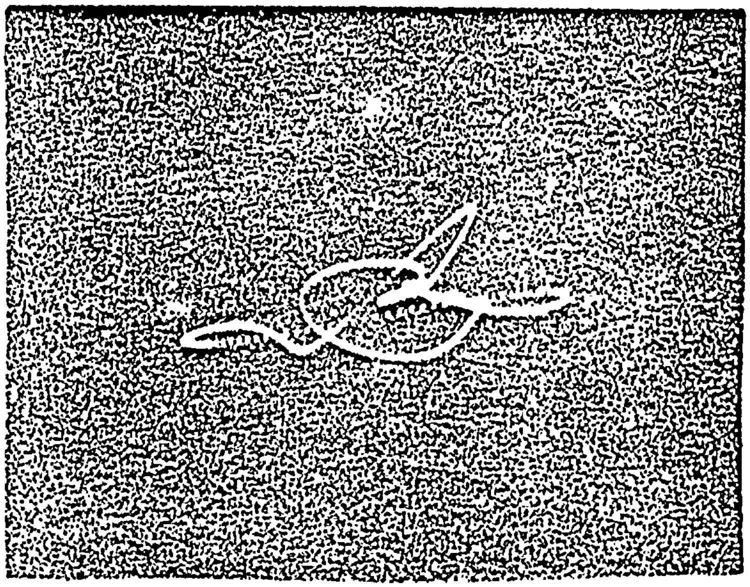


37%

R7C62

2" ATS

11/80



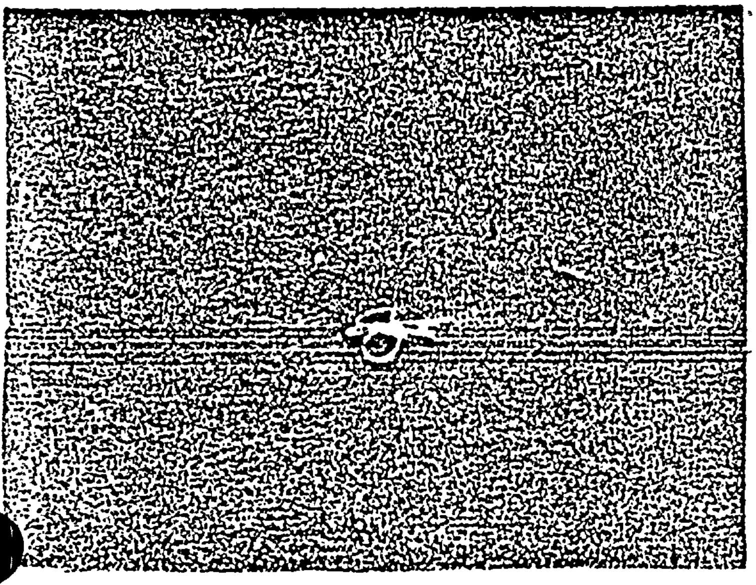
42%

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

5/80

Not Tested

R7C64

2" ATS

11/80

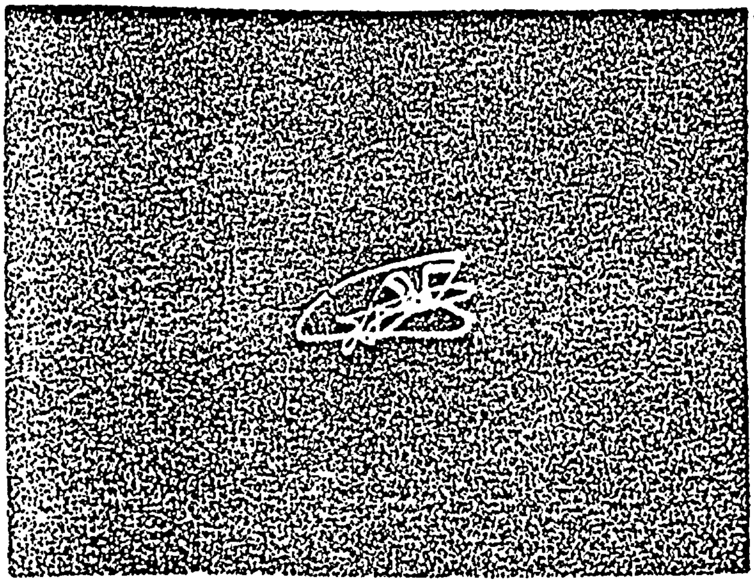


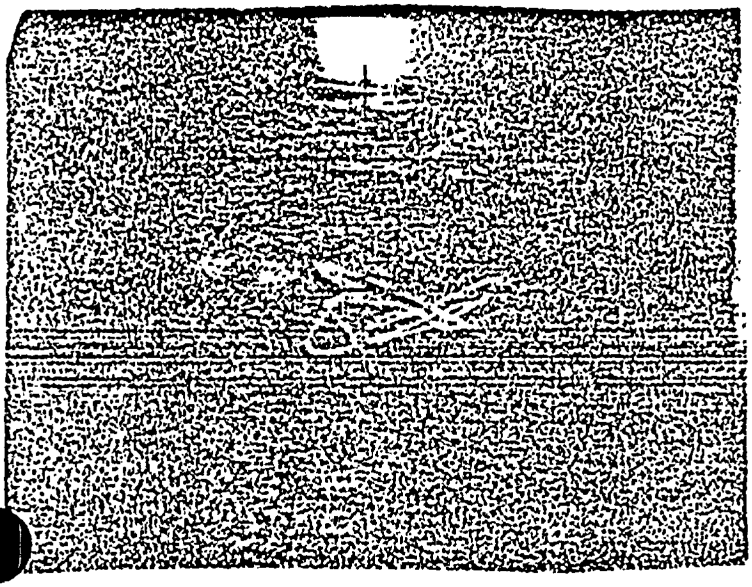
FIG. A-29

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

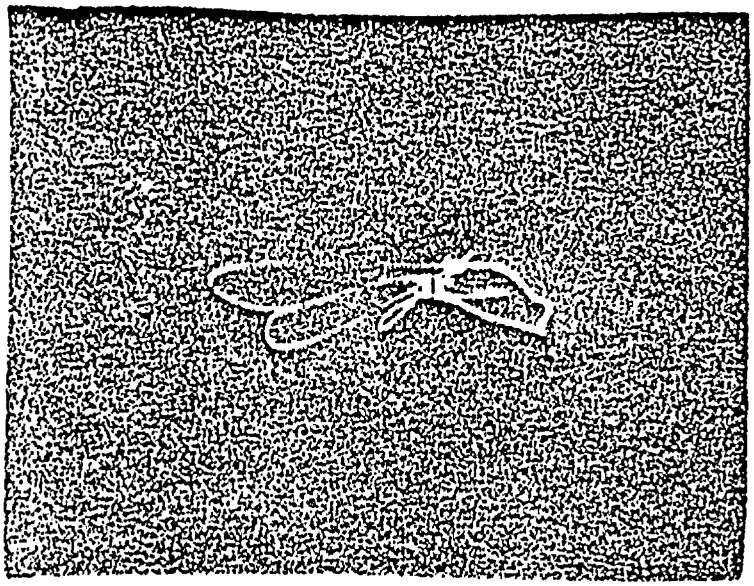
5/80

Not Tested

R7C65

3" ATS

11/80



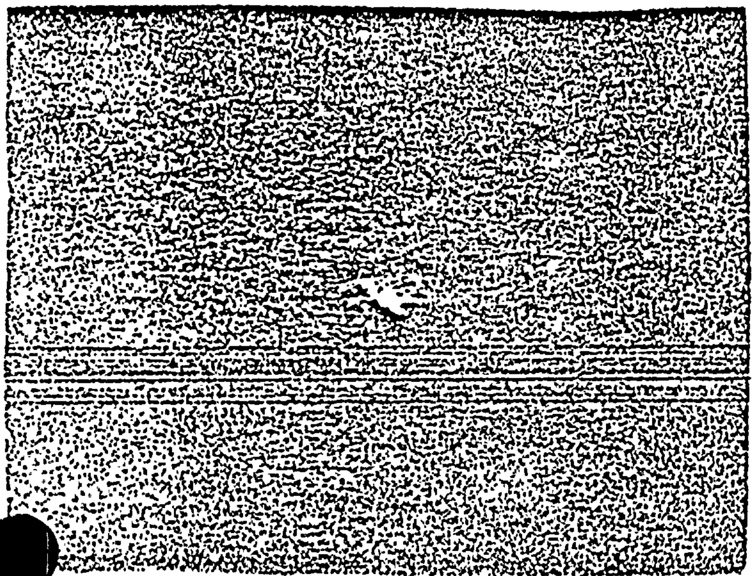
42%

TURKEY POINT #4(FLA)

S/G-B C.L.

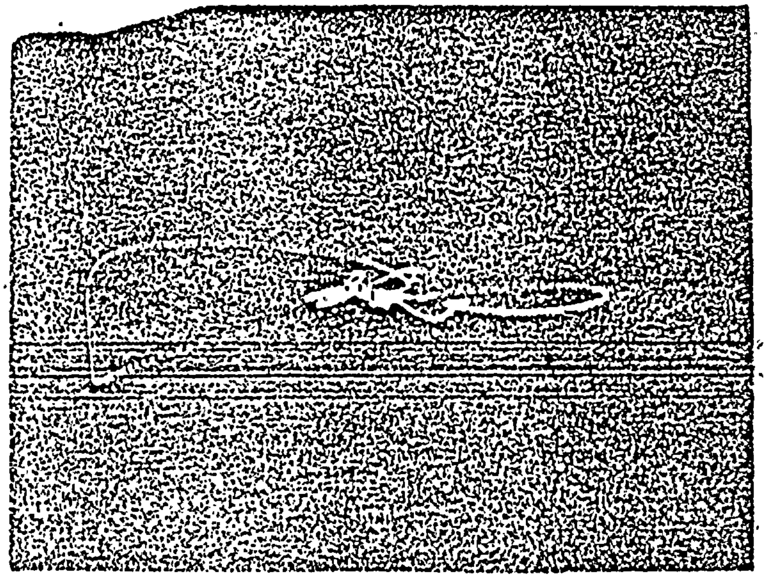
2 Volts/Division

4/79



20%

5/80

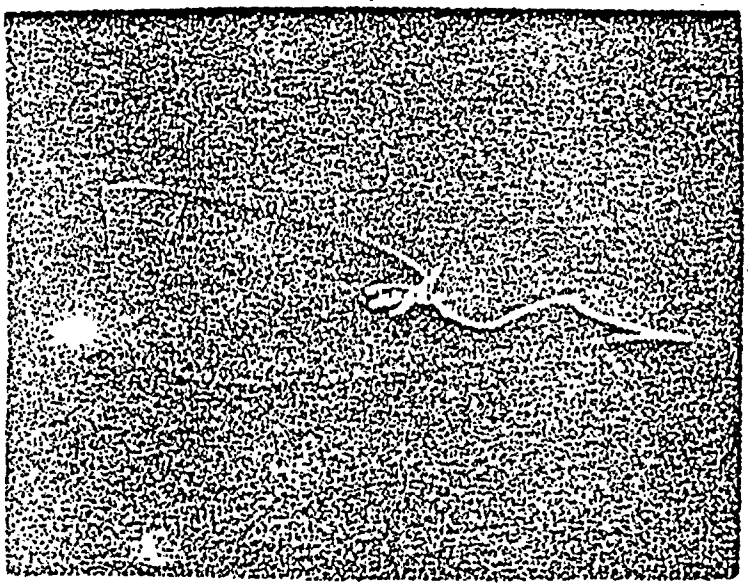


22%

R17C69

3" ATS

11/80



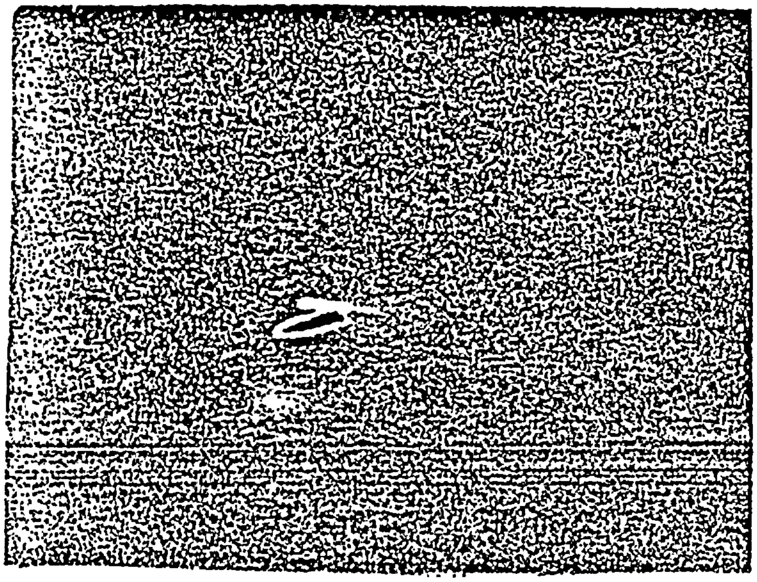
44%

TURKEY POINT #4(FLA)

S/G-C H.L.

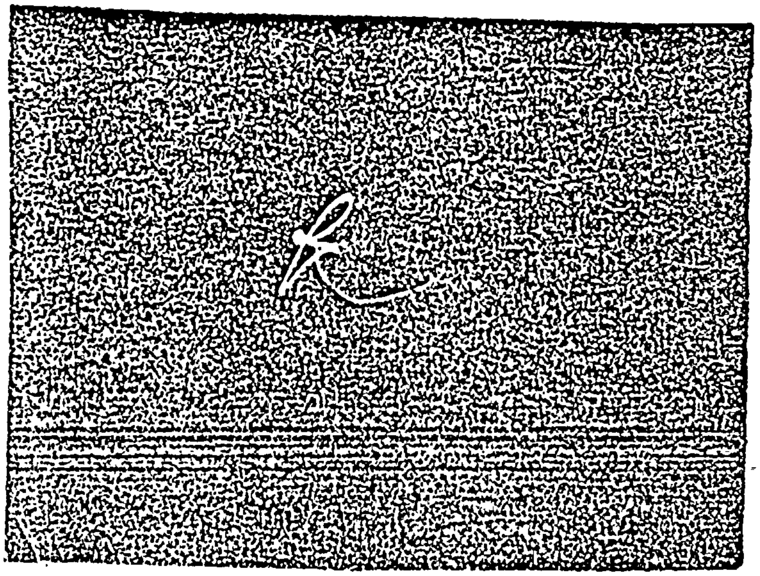
2 Volts/Division

4/79



Not Quantified

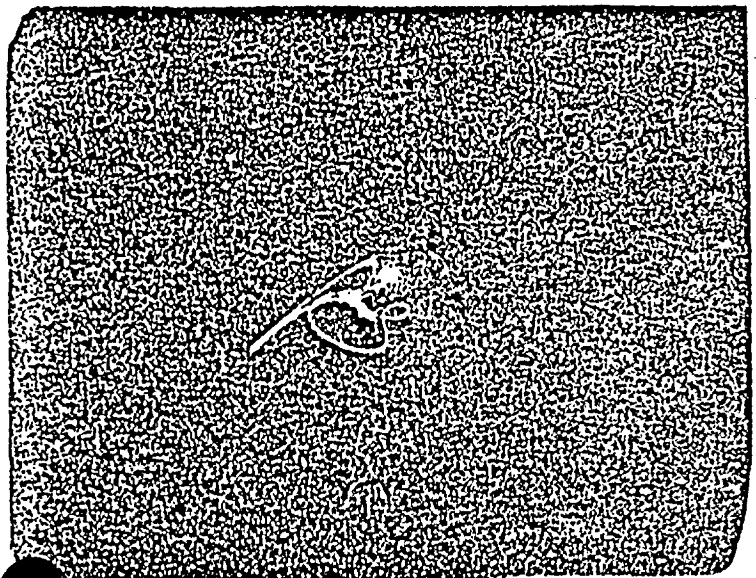
11/80



51%

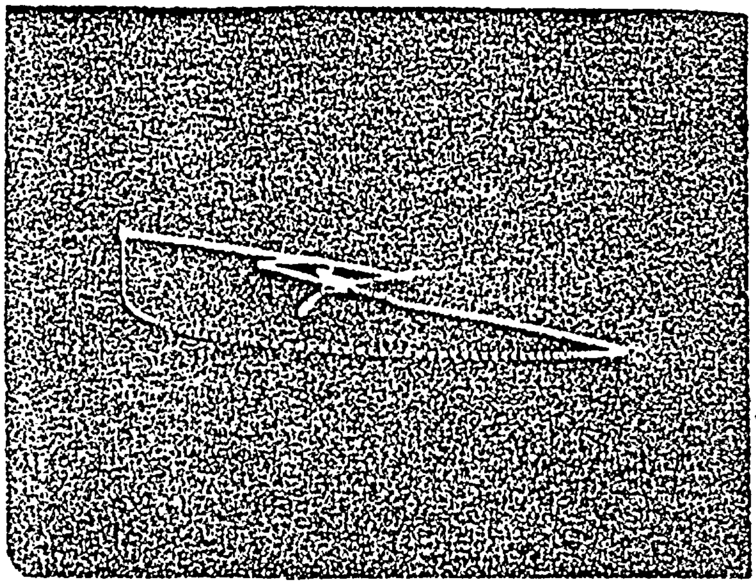
R44C53
1" ATS

5/75



36%

11/80



49%

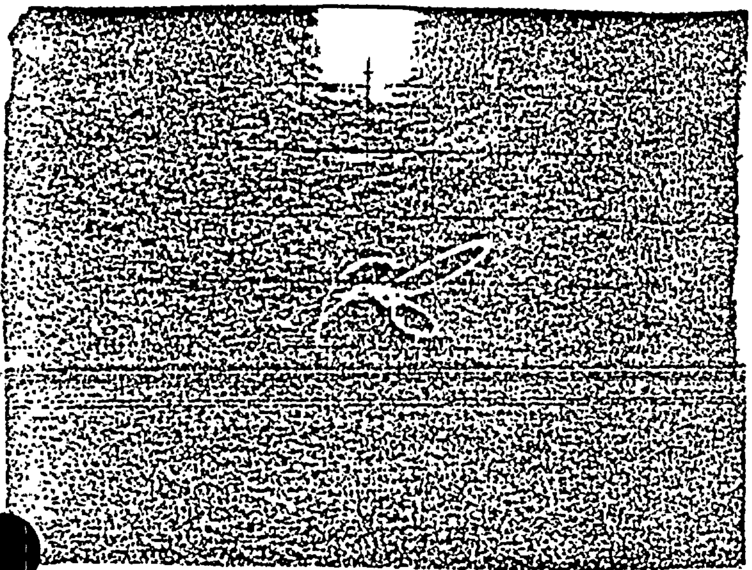
R14C53
2" ATS

TURKEY POINT #4(FLA)

S/G-C C.L.

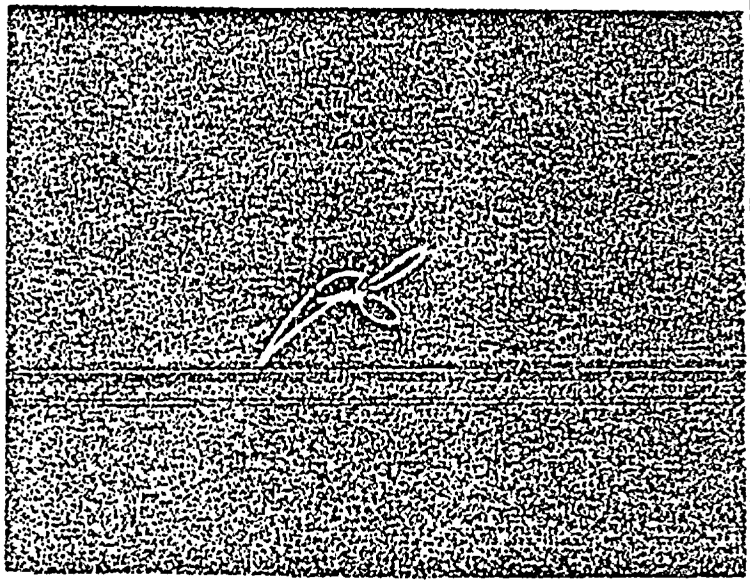
2 Volts/Division

4/79



31%

5/80

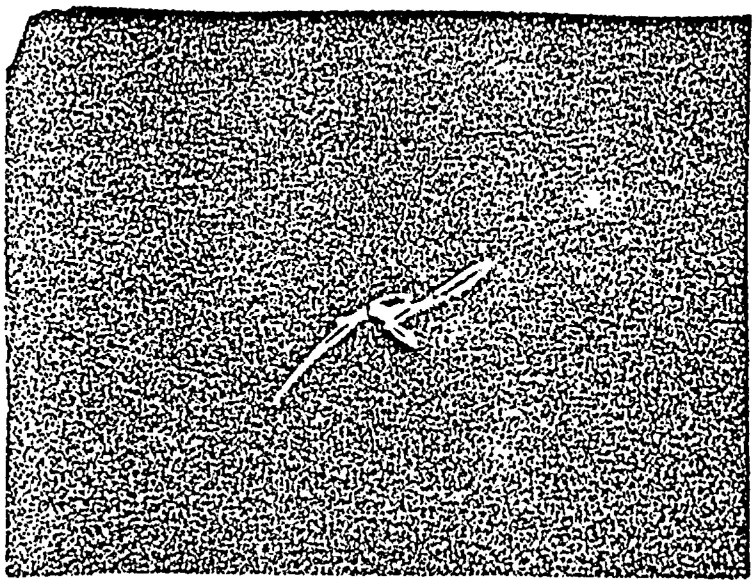


31%

R10C46

2" ATS

11/80



44%

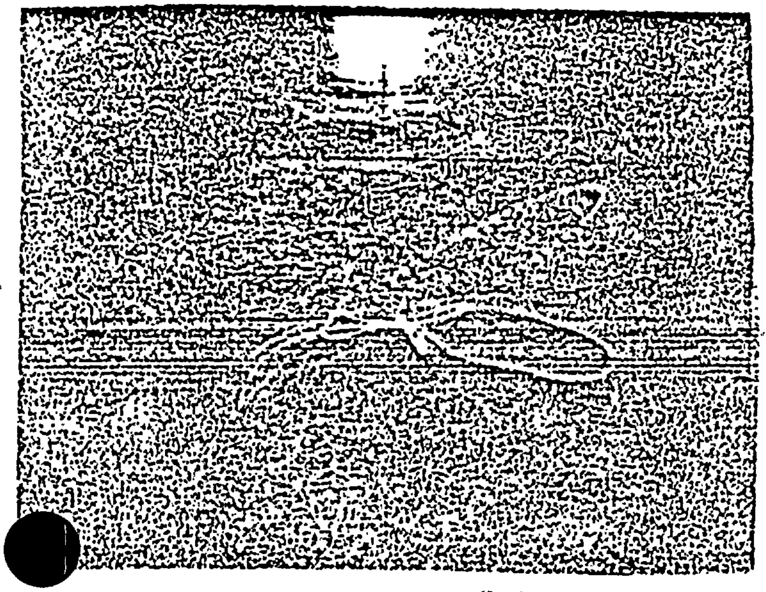
FIG. A 33

TURKEY POINT #4 (FLA)

S/G-C C.L.

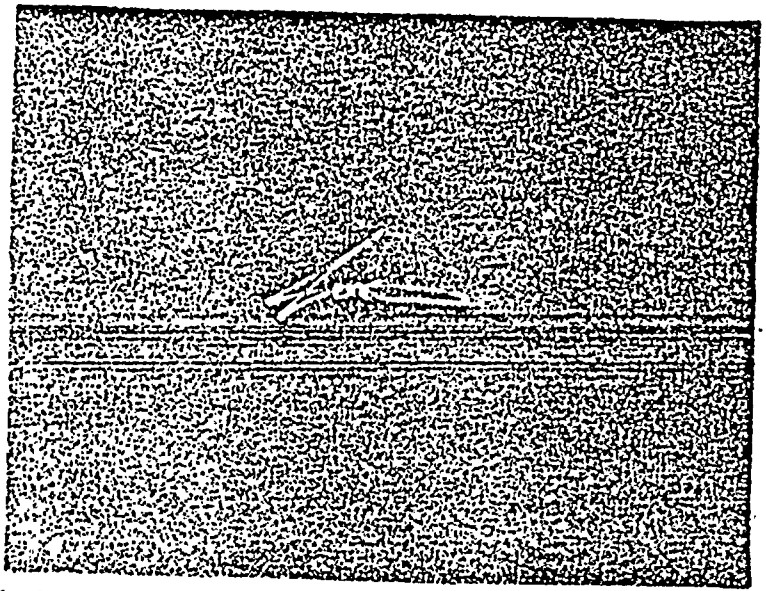
2 Volts/Division

4/79



30%

5/80

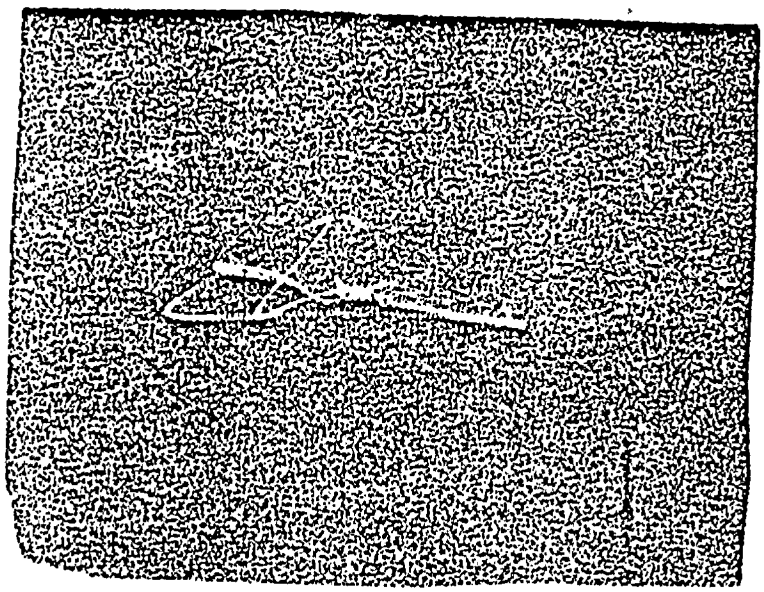


55%

R5C58

TTS

11/80



44%

APPENDIX B

FPL (SERIES 44) SG TUBE INTEGRITY EVALUATION

Minimum Wall thickness Requirement to Safeguard Against Burst and Collapse of Tubing With Localized Degradation at the Top of Tubesheet

On the basis of extensive testing of typical PWR steam generator tubing, it is known that for the straight length tubing the minimum tube wall (t_{min}) requirement to safeguard against burst or rupture during a postulated feed line break (FLB) accident is always more limiting than that for collapse following a postulated LOCA (1)*. Thus, the approach used to establish the minimum required wall thickness for tubing degraded locally at the top of the tubesheet (TTS) consists of (1) computing the t_{min} based on the burst pressure requirement: and (2) verifying that using this t_{min}, the collapse requirement is satisfied for a tube with the maximum expected ovality in the TTS region of the tube bundle. It is to be noted that both the tube burst and collapse strengths used in the following calculations are those associated with the uniform thinning type of defect which is shown to be the most limiting (1). In reality, since thinning tends to be nonuniform, the assumption of minimum ligament being uniform around the entire circumference lends to a somewhat conservative estimate of t_{min}.

Nominal Parameters for the FPL SG Tubing

Outside Diameter, OD = .875 in.
Wall Thickness, t = .050 in.
Inside Diameter, ID = .775 in.
Material, I-600 Mill-annealed
Lower Bound Yield Strength (2),
S_y = 37.8 ksi at Room Temperature
S_y = 30.1 ksi at 600 degrees F
Maximum Ovality in Straight Legs, e_o = 1.5%

* Numbers in brackets designate references at end of Appendix B.

In order to account for the effects of thin wall behavior and the anisotropic yield properties, actual test results, shown in Figure B-2 (1), of uniformly thinned, as manufactured tubing are used. These tests were run at 600 degrees F. The material yield strength was 51.0 ksi at room temperature, and 42.0 ksi at 600 degrees F (based on 12.5% reduction suggested by Figure 79 of Reference 1).

Corresponding to a 74% wall degradation, (t_{min} = .013 inch) the minimum collapse pressure P_c from Figure B-2 is obtained to be 1760 psi (for a defect length of .75 inch). This value is used as the reference collapse pressure of a perfectly round, (this is a conservative assumption) as-manufactured tube thinned uniformly to .013 inch ligament. This value is then adjusted for the actual FPL tubing yield strength of 30,100 psi and ovality of 1.5% using the ANSYS solution discussed above.

For the given ovality and $R_{m/t}$ ratio, the collapse pressure is proportional to the yield strength. Hence, the reference collapse pressure for 74% degraded FPL tubing is:

$$P_C = 1760 \times 30{,}100/42000 = 1260 \text{ psi}$$

From the ANSYS solution in Figure B-1, the ratio of normalized collapse pressure of round tube to a 1.5% oval tube is:

$$\frac{P_o}{P_{1.5}} = \frac{.775}{.97} \simeq .8$$

Hence, the minimum predicted collapse pressure of 74% degraded FPL tubing in the straight leg regions is:

$$P_{1.5} = .8 \times 1260 = 1000 \text{ psi.}$$

Note that if the defects are in the proximity of the tubesheet, the actual resistance to collapse would be increased somewhat due to the end constraint.

Burst Strength Requirements

The maximum primary-to-secondary pressure of 2560 (2) psi across the tube wall occurs during a postulated FLB accident. To safeguard against tube rupture under this loading at 600 degrees F, t_{min} = .013 (2) inch has been established for a nominal .775 inch ID, I-600 MA tubing. That analysis used a conservative lower bound of 10,000 psi room temperature burst pressure for a nominal .875 x .050 wall tubing.

Verification for Collapse Requirement

A number of studies on the external pressure collapse response of typical SG tubing have been reported (1, 3). Even though the tube ovality is known to reduce significantly the resistance to collapse, accurate analytical formulation is difficult to derive because of material anisotropy and increasing ovality under pressure loading (that is, Lagrangian formulation). Additionally, in the case of degraded tubes with a remaining wall on the order of 25% of nominal, the effect of failure mode being elastic buckling rather than plastic collapse should also be considered.

For the lack of a comprehensive, unified theory encompassing the effects of all the above variables, the following conservative approach is needed for verification of t_{min} against collapse.

From the results in Reference (3), it is observed that the limit analysis theory correlates well with the test results of stress-relieved tubing which is believed to have less anisotropic yield properties than as-manufactured tubing. The theoretical prediction is rather excellent for specimens with small initial ovalities. Nevertheless, in order to account for continued increase in ovality under the external pressure loading, a large-deformation finite element solution (ANSYS STIF48) using elastic-perfectly plastic shell behavior is utilized for the actual verification. The finite element solution along with the limit analysis theory and actual test results is shown in Figure B-1.

For the FPL SG units, the maximum secondary to primary pressure due to LOCA is 770 psi (4). The required minimum collapse pressure in accordance with the Section III criterion is 860 psi (770/.9). Since the predicted strength is in excess of the required minimum, t_{min} = .013 inch is verified against failure due to collapse.

References

1. Vagins, M., et al., "Steam Generator Tube Integrity Program - Phase I Report", NUREG/CR-0718, September, 1979.

2. Smith, P.G., and Sun, C.L., "CPL Steam Generator Tube Plugging Criteria Calculations", WTD-SM-77-058, Revision 1, July, 1977.

3. Small, N.C., "Plastic Collapse of Oval Straight Tubes Under External Pressure," ASME Paper 77-PVP-57, June, 1977.

4. Turkey Point Units 3 & 4 LOCA Analyses.

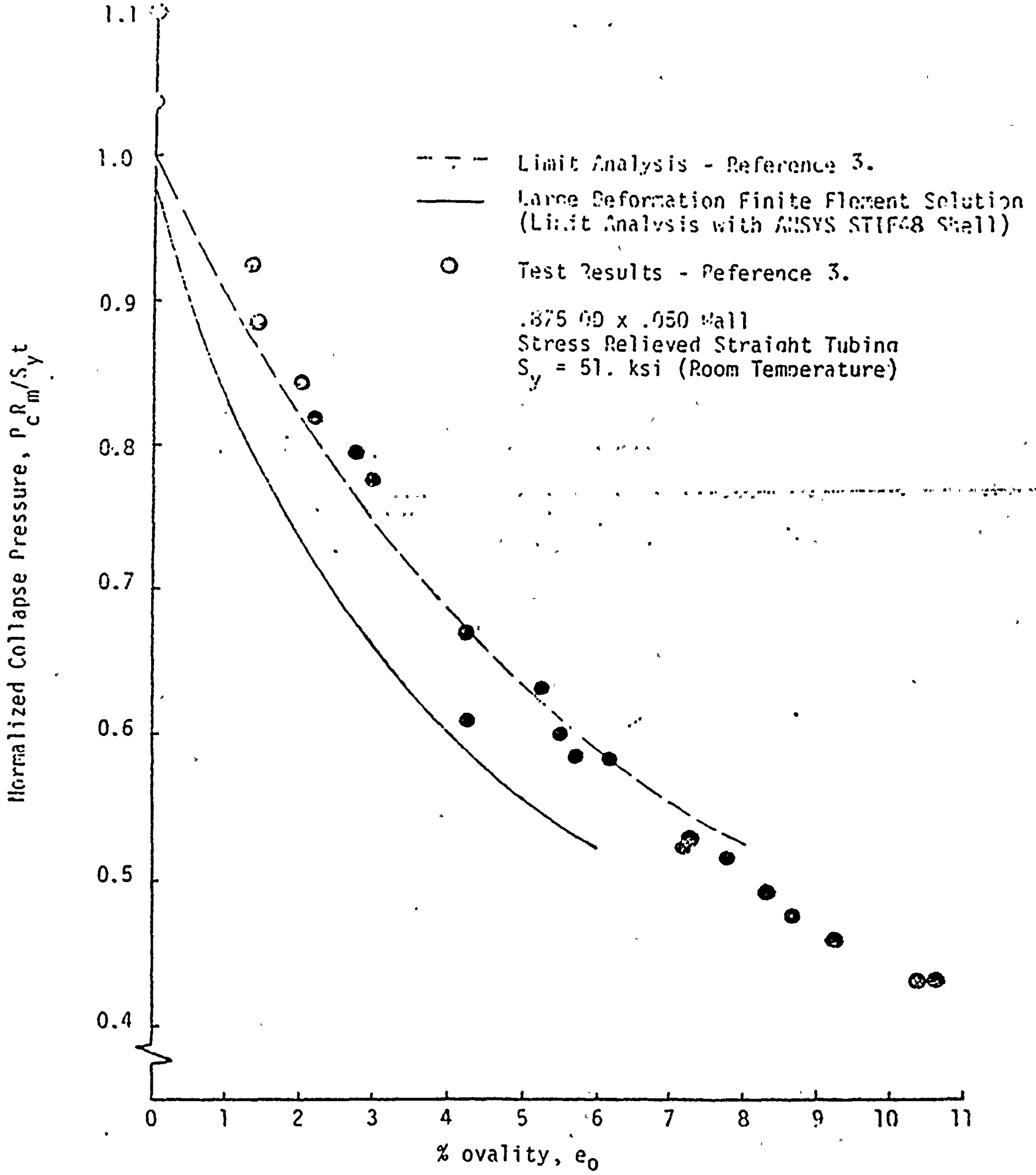


FIGURE B-1 COLLAPSE PRESSURE OF STRAIGHT OVALIZED TUBES - CORRELATION BETWEEN TEST AND ANALYSES

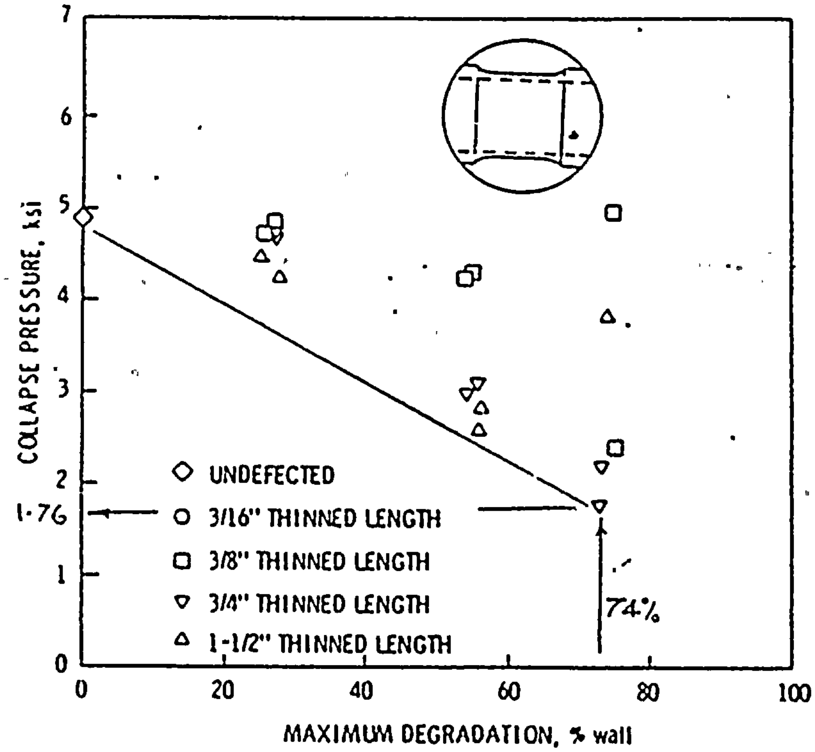


FIGURE B-2 Collapse Pressure Data for 0.875 x 0.050 Uniform Thinning Specimens - Ref. [1]

ATTACHMENT C

ATTACHMENT - FPL SYSTEM LOAD CONDITIONS FOR JULY - OCTOBER 1981

FORECASTED PEAK LOADS (MW)

JULY	AUG.	SEPT.	OCT.
9610	9630	9630	8620

NOTE (1) These forecasted peaks could very probably be low, as last year's actual July peak load was 9632 MW.

NOTE (2) The southeast Florida loads are 70% of the above system loads.

NOTE (3) The generation transfer limit into southeast Florida during this summer (assuming the worst case transmission line out of service) is 1150 MW at the 9630 MW load level.

FPL'S TOTAL INSTALLED CONTINUOUS SUMMER CAPABILITY FOR SOUTHEAST FLORIDA.

7743 MW [6438 MW STEAM + 1305 MW DIESEL & GAS TURBINES].

NOW ASSUMING BOTH TURKEY POINT UNITS ARE OUT OF SERVICE (646 MW PER UNIT).

7743 - 1292 = 6451 MW AVAILABLE

SINCE IMPORT LIMIT IS 1150 MW:

6451 + 1150 = 7601 MW TOTAL AVAILABLE TO SOUTHEAST FLORIDA

SOUTHEAST FLORIDA FORECASTED PEAK LOAD FOR THIS SUMMER IS:

9630 MW X .7 = 6741 MW

RESERVES FOR SOUTHEAST FLORIDA ARE:

7601 MW - 6741 MW = 860 MW

$$\frac{860 \text{ MW}}{6741 \text{ MW}} = 12.8\% \text{ RESERVE}$$

THIS RESERVE IS CONSIDERABLY BELOW THE RECOMMENDED 20%. NOTE ALSO THAT THIS CALCULATION ASSUMES NO OTHER UNITS OUT OF SERVICE, HENCE ANY OTHER UNIT PROBLEM WOULD MAKE THE CONDITION MORE SEVERE.

Attachment B

FLORIDA POWER & LIGHT COMPANY

February 27, 1981
L-81-88

Office of Nuclear Reactor Regulation
Attention: Mr. Steven A. Varga, Chief
Operating Reactors Branch #1
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Varga:

Re: Turkey Point Unit 4
Docket No. 50-251
Steam Generator Tube Wastage Information

Amendment 54 to the Turkey Point Unit 4 Facility Operating License authorized six months of operation subject to the submittal of confirmatory data regarding tube wastage. FPL received the specific items requested by the NRC on January 30, 1981.

The attached report provides the tube wastage predictions and other associated supplemental information requested by the Staff. The analysis, using conservative assumptions, confirms that the currently authorized 6 month operating period is conservatively bounded by the tube wastage predictions. In addition, with respect to tube wastage, the analysis supports a minimum operating period in excess of 14 equivalent full power months.

Very truly yours,

Robert E. Uhrig

Robert E. Uhrig
Vice President
Advanced Systems & Technology

REU/JEM/ras

Attachment

REGULATORY DOCKET FILE COPY

cc: J. P. O'Reilly, Region II
Harold F. Reis, Esquire

Dupe of
8104060572

FLORIDA POWER AND LIGHT COMPANY

TURKEY POINT UNIT 4

SUPPLEMENTAL INFORMATION ON

S/G TUBE WALL THINNING

During the 11/80 outage, the steam generator tubes at Turkey Point Unit 4 were inspected as required by the stipulations in the plant operating license. The eddy current testing (ECT) indications showed some instances of apparent tube degradation above the top of the tubesheet. A review of the ECT tapes from the previous inspection showed that in the steam generator (B-cold leg) with the highest apparent tube degradation, 46 tubes with indications had been included in the previous inspection program. These 46 tubes with two successive estimates of tube wall degradation allow an estimated corrosion rate to be established. The rate calculated for these 46 tubes is 8.41% for 4.75 EFPM. This converts to 1.77% tube wall loss per EFPM. The detailed analysis of the steam generator inspection is attached in Appendix A.

The establishment of an estimate corrosion rate allows an operating interval to be determined. The present tube plugging criteria for Turkey Point Unit 4 require that tubes with ECT indications of 40% or greater shall be plugged. This means that the largest indication still in service is 39%. A 39% indication converts to 61% of the tube wall remaining.

The tubes in these steam generators are nominally 7/8 inch O.D. by .050 inch wall. The minimum tube wall that is required to maintain tube pressure integrity during a plant faulted condition event in the area near the top of the tubesheet is .013 inches. The detailed steam generator tube integrity evaluation supporting this minimum tube wall is contained in attached Appendix B. A remaining tube wall of .013 inches is 26% of the nominal tube wall. The difference between the minimum required tube wall (26%) and the minimum tube wall in service (61%) is the margin in tube wall thickness if tube wall degradation should continue; this margin is 35% of the tube wall. Using the estimated

corrosion rate of 1.77 per EFPM, an operating period of 19.88 EFPM can be justified. The quantification of ECT indications has some tolerance associated with the depth of the indication. The ECT tolerance applied by the NRC staff in the 35% to 40% range is $\pm$ 9%. For conservatism, it shall be assumed that the largest indication still in service is increased by 9%. Therefore, the 39% indication becomes 48% and the remaining wall is 52%. The difference between 52% and 26% is the conservative amount of tube wall margin if tube degradation should continue. The 26% tube wall margin combined with the estimated corrosion rate allows an operating period of 14.7 EFPM.

Considering the estimated operating intervals, a six month operating interval for the Turkey Point Unit 4 is considered to be a conservative operating interval.

APPENDIX A

EDDY CURRENT EVALUATION

TURKEY POINT UNIT 4, NOVEMBER, 1980

STEAM GENERATOR INSPECTION

I. INTRODUCTION

An evaluation of the eddy current data obtained in the November, 1980 steam generator inspection at Turkey Point Unit 4 was made in response to the NRC request for additional information relative to Amendment 54 authorizing operation of the unit for six equivalent months beginning January 13, 1981.

II. EXPANDED PROGRAM - NOVEMBER, 1980 INSPECTION

All pluggable thinning indications were found during the original eddy current testing program. The expanded program performed in accordance with Regulatory Guide 1.83 did not reveal any additional plugging indications.

III. EDDY CURRENT READINGS

Figures A-1 to A-6 show the distribution of eddy current indication ≥20% for each leg of the three steam generators. The preponderance of indications at low percentages, i.e. less than 40%, strongly suggests thinning as the nature of the tube degradation since detection of cracking by eddy current techniques is insensitive below about 40% wall penetration.

The eddy current readings for each of the pluggable thinning indications found in the November, 1980 inspection, including the coresponding readings obtained in April, 1979 and in May, 1980, as requested by the staff, as well as all previous indications recorded, are listed in Table A-1.

IV. AVERAGE INCREMENTAL THINNING CALCULATIONS, MAY, 1980 TO NOVEMBER, 1980

The average incremental wall thinning increase (in terms of percent of wall penetration) was calculated for each steam generator hot and cold leg, relative to the May, 1980 inspection for all tubes exhibiting thinning indications equal to or greater than 20% in December, 1980 and for which indications equal to or greater than 20% were observed in the May, 1980 inspection. The indications were observed at tube elevations from just above the top of the tubesheet to about 3 inches above the top of the tubesheet. No tubesheet crevice indications were observed in either the hot or cold legs of any of the generators inspected. The pertinent statistics are summarized in TAble A-2. For the case where

the only positive average incremental thinning increase was observed (steam generator B cold leg) the actual data from which the average was calculated are given in Table A-3.

In addition, histograms (Figs. A-7 to A-11) are presented to graphically display the number of indications observed over each 5% incremental change in eddy current readings between the May, 1980 and December, 1980 inspections for those tubes for which readings equal to or greater than 20% were reported in both inspections. No histogram was prepared for the steam generator C hot leg data since only one tube could be compared for the two inspections.

From Table A-2, it is noted that except for the cold leg of steam generator B, where a positive average increment was calculated, and the hot leg of steam generator C, where only a single comparison was possible, the remaining four comparisons yielded apparently negative average incremental thinning for the period from May, 1980 to November, 1980. This result is not indicative of an actual decrease in tube thinning. Rather, it reflects the variability in the eddy current method itself as well as possible human factors involved in evaluating the eddy current signals. However, in each case (Steam Generator A, hot and cold leg; Steam Generator B, hot leg; and Steam Generator C, Cold Leg), these results suggest little or no thinning has occurred in the time period studied.

In the case of Steam Generator C, hot leg, where only one indication could be compared between the two inspection periods, only seven indications ≧20% were observed, suggesting a low degree of thinning activity.

V. DISCUSSION

In the case of Steam Generator B, cold leg, comparison of the average incremental thinning increase with results from the other steam generator legs suggests that there may be a small but finite increment in tube thinning which may not be explainable solely on the basis of inherent uncertainties in the eddy current method. However, comparisons of the May, 1980 and November, 1980 eddy current signals from the pluggable tubes suggest that the presence of new or increased denting may have affected the estimates of the eddy

current phase angles leading to possible overestimates of the depth of penetration in some of the December, 1980 signals.

Photographs of the November, 1980 eddy current signals from all of the plugged tubes, comparing November, 1980 eddy current signals with previous inspections, are shown in Figs. A-12 to A-33. In most of the photographs, denting can be seen to have affected the nature of the eddy current signals. For example, in Figure A-20, the eddy current signals and estimated wall thinning(%) for tube R22-C44 are displayed for the 4/79, 5/80 and 11/80 inspections. The component of the eddy current signal due to denting (indicated by arrows marked "1" on the figures) is seen to have increased in each of the inspections. The effect of the contribution of denting to the signal is to rotate, or deflect the portion of the signal associated with wall penetration (indicated by arrows marked "2" on the figures) toward higher phase angles, or greater apparent wall penetration.

In the present state of the art of eddy current inspection techniques, the effect of superimposition of denting and thinning signals cannot be quantified. Nevertheless, based on the above discussion of the nature of generation of the observed eddy current signals, it is believed that the actual tube wall penetration for many of the (plugged) tubes may be significantly less than has been reported.

Similar effects were observed for at least 12 of the 16 pluggable tubes in this leg of Steam Generator B, including R17-C69, for which the largest apparent increase of wall thinning was calculated from the reported field data, as well as for the pluggable tubes found in the other two steam generators.

On the basis of the highest calculated average incremental change from May, 1980 to December, 1980, 8.41% in SG/B cold leg, the apparent degradation for this period of operation consisting of 4.75 Effective Full Power Months (EFPM) is 1.77%/EFPM. Assuming the same rate of thinning over the present operating period, a tube operating with the largest unplugged indication of 39% might experience further wall loss of 10.6% over an additional operating period of 6 EFPM. Allowing for the staff's

estimate of 9% for errors attributable to the eddy current method,* such a tube might show an indication of 59% in terms of wall penetration after 6 EFPM of operation. The remaining wall ligament would then consist of 41% of the original wall thickness.

As shown in Appendix B to this submittal, the minimum wall requirement for postulated accident conditions for straight sections of the tube is 0.013 inches, or 26% of the nominal 0.050 inch tube wall. This limit would permit operation for up to 14.7 EFPM at the calculated rate of degradation, i.e. 1.77% per EFPM. Further, if the tubes plugged in steam generator B, cold leg, are deleted (on the basis that these tubes have been removed from service) from the data base (Table A-3) from which the calculations were made to determine the highest average thinning rate, the calculated average incremental thinning would be only 6.25% rather than 8.41%, and the thinning rate calculated over 4.75 EFPM would be only 1.32% EFPM rather than the conservatively calculated 1.77% EFPM. Using a thinning rate of 1.32% EFPM, and following the same method of calculation described above, margin is available for operation to 19.7 EFPM. Thus, ample margin is available. for operation in excess of 6 additional EFPM even given the conservatisms assumed.

VI. VERIFICATION OF INSPECTION COVERAGE

A review will be made to verify that all unplugged tubes with reported indications ≥ 20% in previous inspections will be inspected at the next outage.

* However, Westinghouse believes that for indications in the range of 40 - 50%, a lower estimate, i.e. about 7%, is more appropriate for errors attributable to the eddy current method.

WORK SHEET
...NGHOUSE FORM 8295 E

TABLE A-1
TURKEY POINT UNIT #4 EDDY CURRENT INDICATIONS FROM
TUBES PLUGGED FOR THINNING-NOVEMBER,1980 STEAM GENERATOR INSPECTION

STEAM GENERATOR	TUBE #		Eddy Current Indications For Inspections Tested							
	Row	Col.	8/74	5/75	4/76	6/77	8/78	4/79	5/80	11/80
A (HL)	9	21	33	38	38					45
" "	11	22	22	<20						58
" "	6	75		27						62
B (HL)	9	81		<20	<20					51
B (CL)	14	29		36	38	27	21	39	33	46
" "	12	30		36	28	27	23	35	35	53
" "	23	39		39	32	21	<20	NDD**		43
" "	24	39			36	29	23	38	31	44
" "	24	40		36	27	21	23	<20	24	41
" "	11	44		27	27	27	29	24	36	53
" "	22	44		21	31	24	27	28	28	45
" "	10	46		<20	<20				37	45
" "	11	46		<20	<20				39	43
" "	13	46							33	51
" "	22	46		34	35	32	36	32	32	47
" "	23	46		34	34	28	32	35	32	41
" "	10	47						22	39	47
" "	7	62		37	35	30	30	31	37	42
" "	7	64		25	25	22	<20	NDD		57
" "	7	65		32	29	27	<20			42
" "	17	69		29	23	27	23	20	22	44
C (HL)	14	53	25	36	21	<20				49
" "	44	53								51
C (CL)	10	46		32	21	35	34	31	31	44
C (CL)	5	58		27			29	30	33	44

** NDD=No Detectable Defect
* Blanks Indicate no Data Available

TABLE A-2

SUMMARY OF TURKEY POINT UNIT #4 STEAM GENERATOR TUBING INCREMENTAL WASTAGE FROM MAY, 1980 TO November, 1980

	S/G A		S/G B		S/G C	
	HL	CL	HL	CL	HL	CL
Average incremental wastage (% wall thickness)	-3.82%	-2.23%	-1.14%	8.41%	3%	-1.65%
Number of Tubes Compared	11	219	21	46	1	132
Standard Deviation	3.0	4.1	5.9	6.4	-	4.5

TABLE A - 3

TURKEY POINT UNIT #4

STEAM GENERATOR B COLD LEG

Tubes With ≥ 20% Eddy Current Indications in Both 11/80 and 5/80

Tube I.D. R	Tube I.D. C	5/80 Indication (%)	11/80 Indication (%)	Change (%)
14	29	33	46	13
12	30	35	53	18
18	36	32	36	4
15	37	24	39	15
23	38	23	28	5
24	39	31	44	13
24	40	24	41	17
23	43	25	39	14
11	44	36	53	17
22	44	28	45	17
21	45	24	32	8
7	46	29	37	8
8	46	27	32	5
10	46	37	45	8
11	46	39	43	4
13	46	33	51	18
15	46	25	28	3
21	46	22	30	8
22	46	32	47	15
23	46	32	41	9
24	46	28	38	10
25	46	25	36	11
8	47	28	38	10
10	47	39	47	8
24	47	31	39	8
26	47	21	29	8

TABLE A - 3 (Cont'd)

TURKEY POINT UNIT #4

STEAM GENERATOR B COLD LEG

Tubes With ≥ 20% Eddy Current Indications in Both 11/80 and 5/80

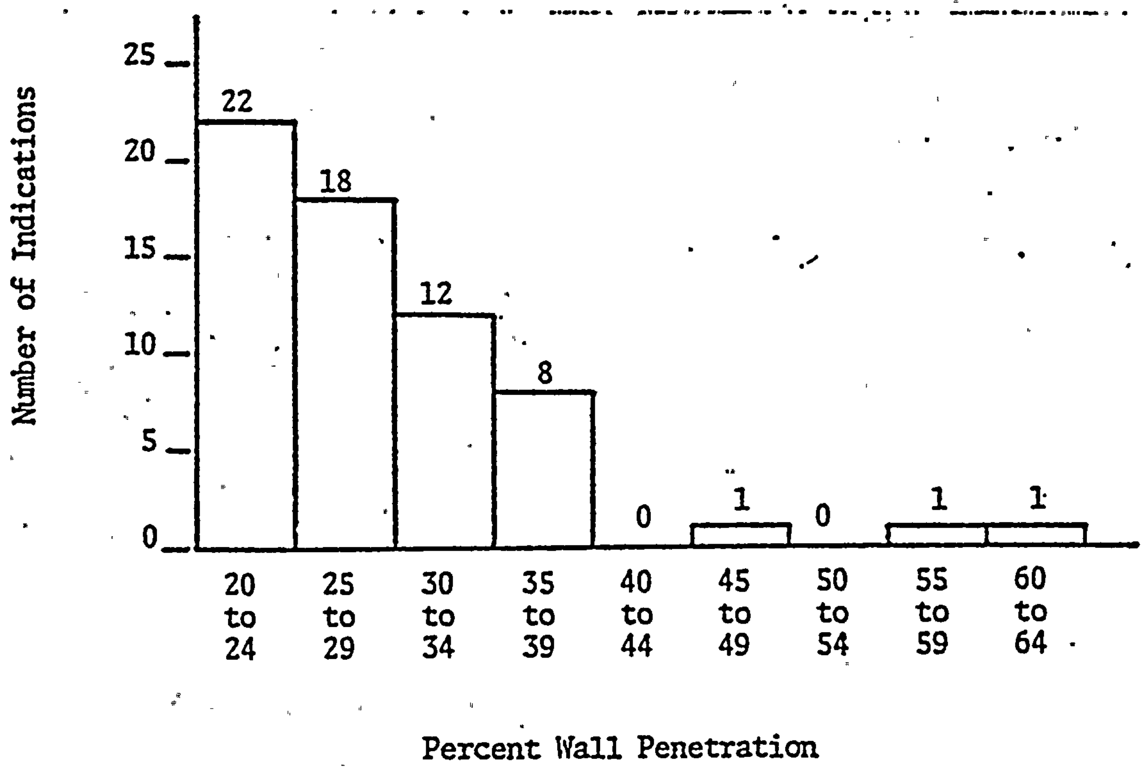
Tube I.D. R	Tube I.D. C	5/80 Indication (%)	11/80 Indication (%)	Change (%)
9	48	37	39	2
10	48	21	31	10
12	48	33	32	-1
23	48	21	38	17
24	48	30	38	8
25	48	34	38	4
26	48	27	35	8
10	49	24	33	9
24	49	30	39	9
23	50	28	39	11
24	50	32	36	4
8	56	27	21	-6
7	62	37	42	5
9	62	24	35	11
17	62	31	32	1
18	63	31	37	6
8	67	37	29	-8
8	68	32	28	-4
17	69	22	44	22
7	71	22	27	5

Total number of tubes compared = 46
Average change = 8.41%
Standard Deviation = 6.38

TURKEY POINT 4

S/G A HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION



TURKEY POINT 4

S/G A COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION

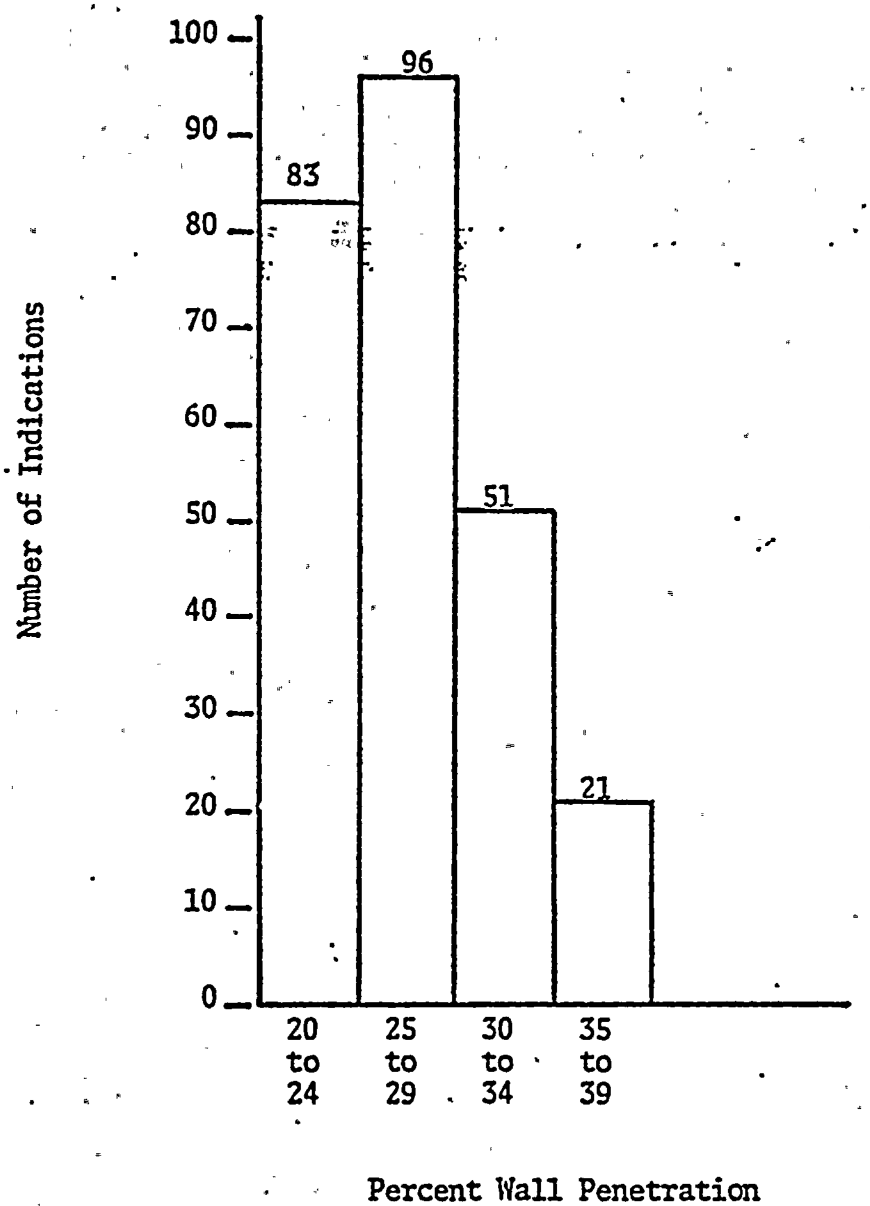


FIGURE A - 3

TURKEY POINT 4

S/G B HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥20%

NOVEMBER 1980 INSPECTION

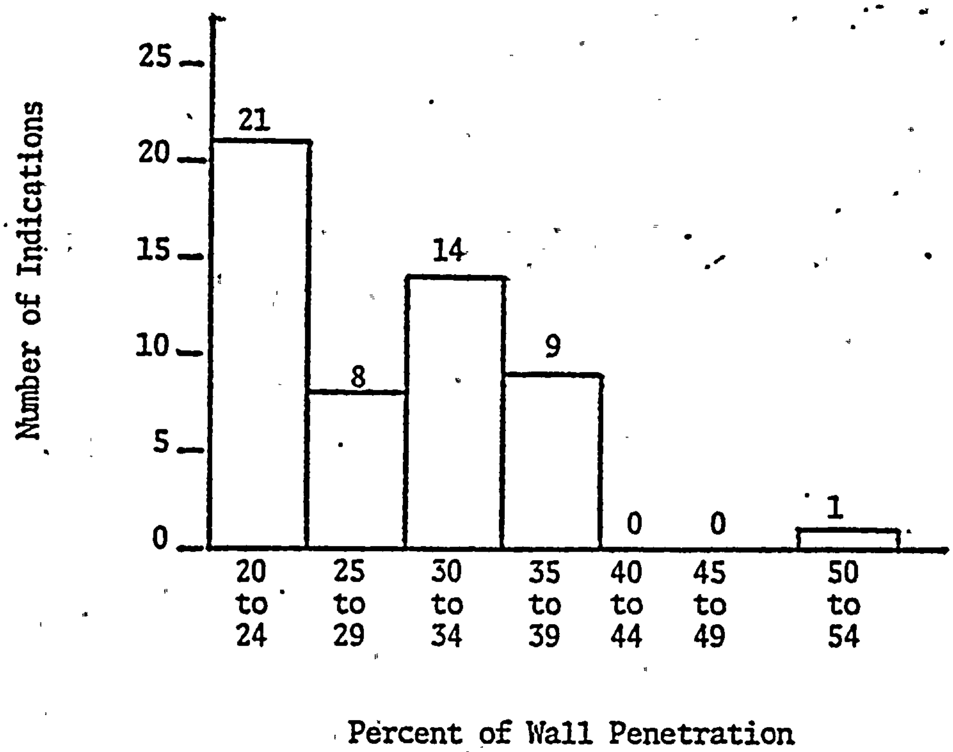
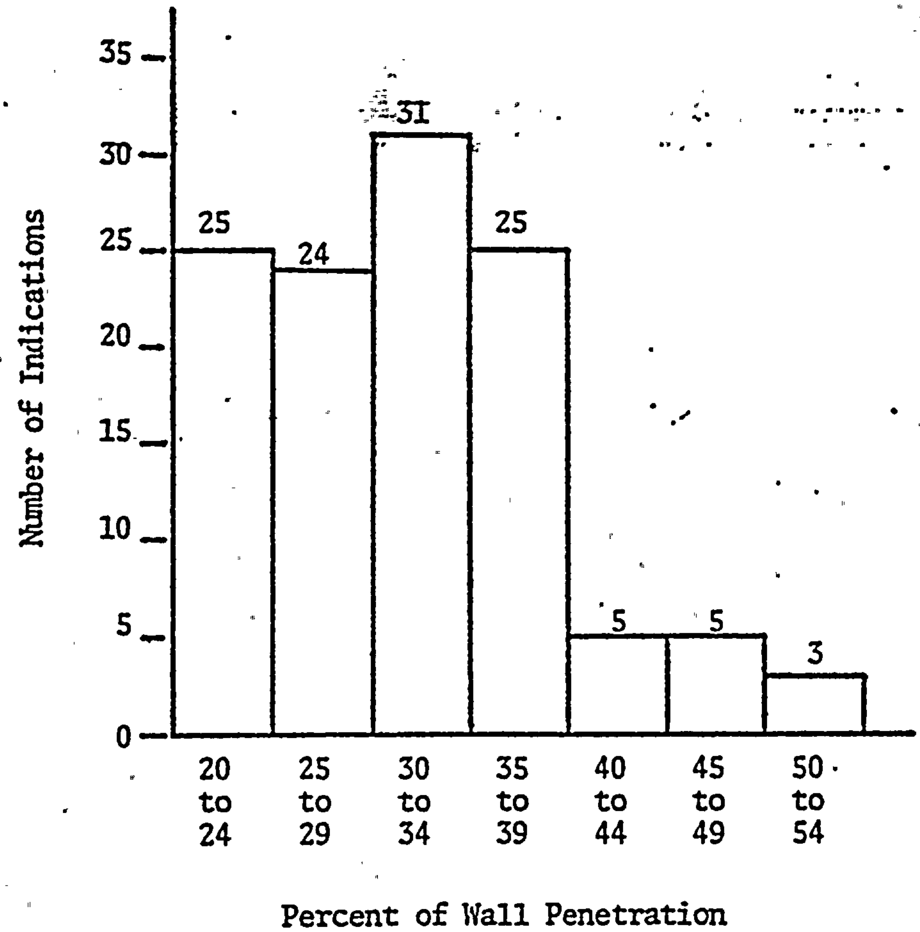


FIGURE A - 4

TURKEY POINT 4

S/G B COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%
NOVEMBER 1980 INSPECTION

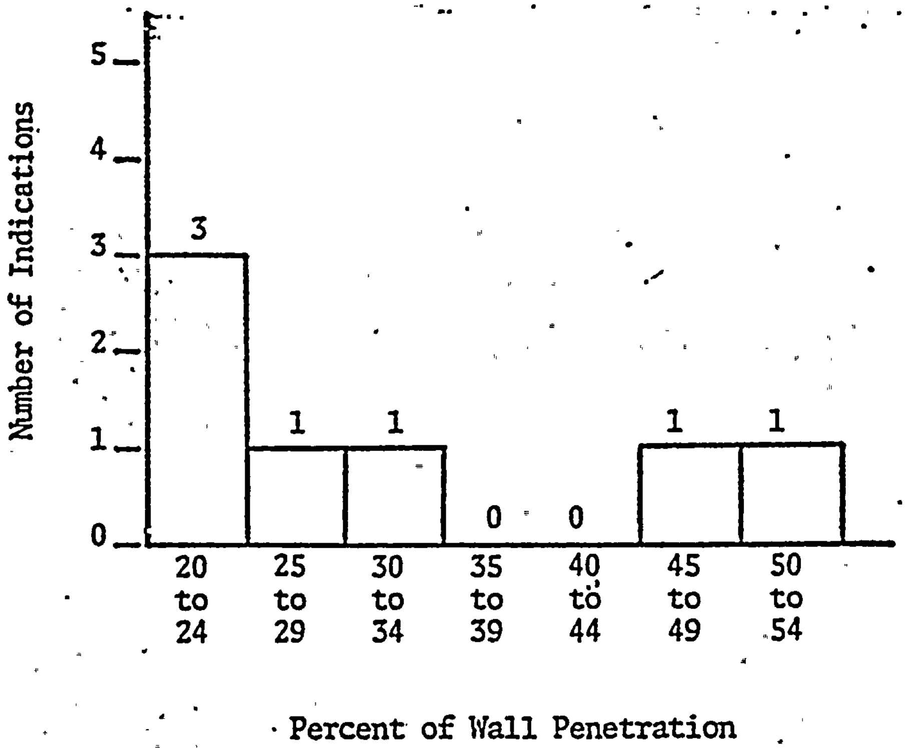


TURKEY POINT 4

S/G C HOT LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥ 20%

NOVEMBER 1980 INSPECTION

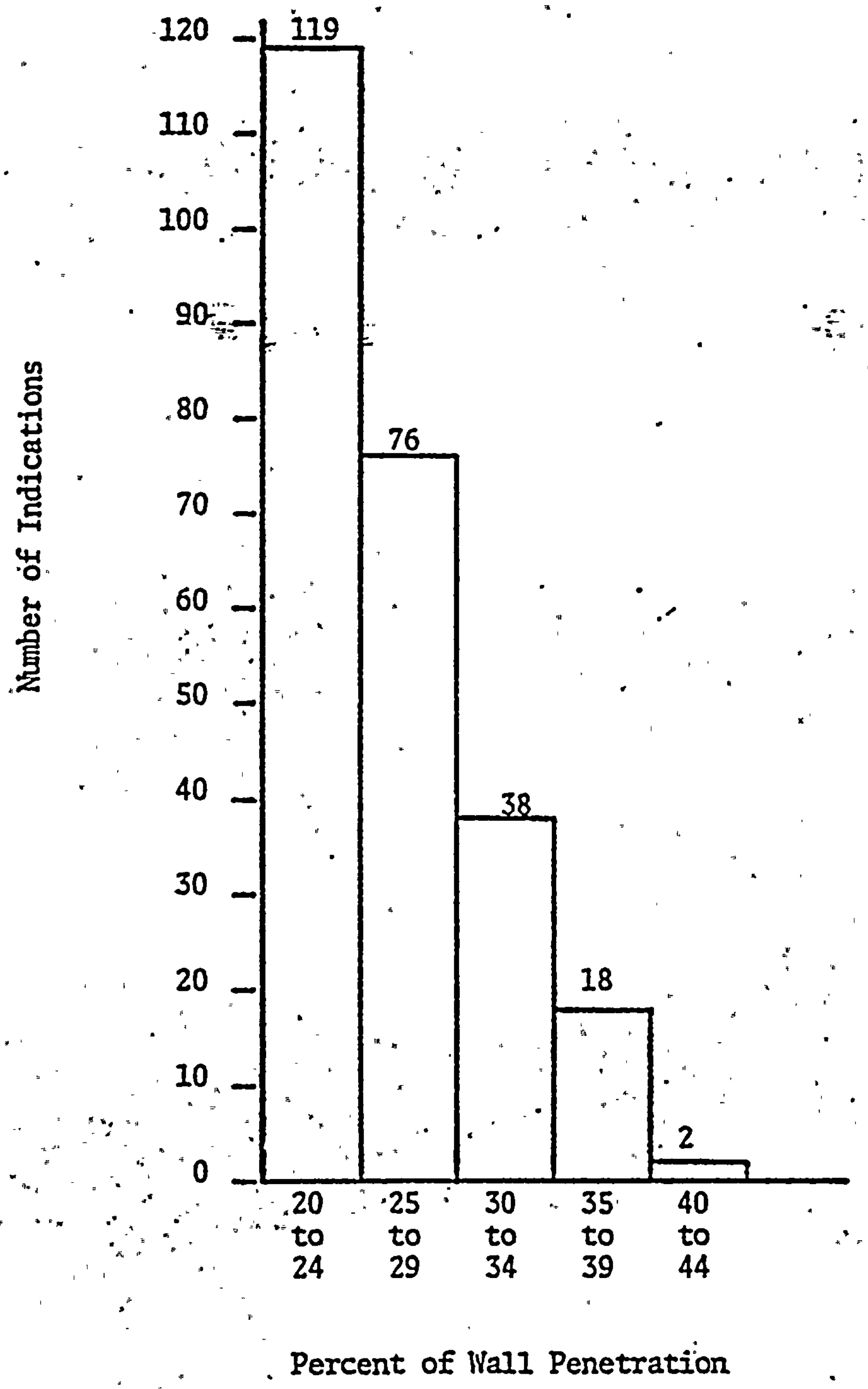


TURKEY POINT 4

S/G C COLD LEG

DISTRIBUTION OF EDDY CURRENT INDICATIONS ≥20%

NOVEMBER 1980 INSPECTION



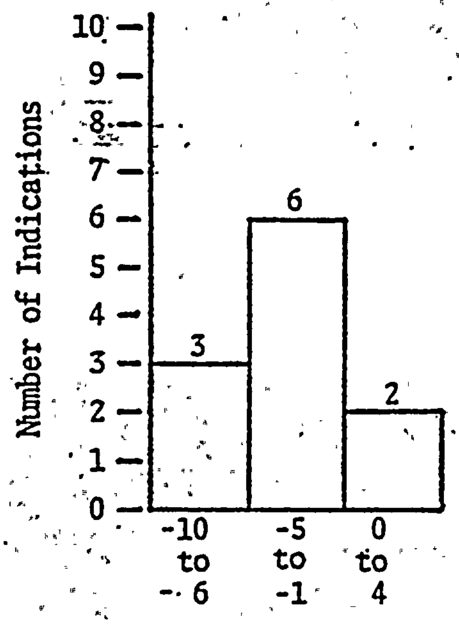
TURKEY POINT 4

S/G A INLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points 11

Average Change -3.82



Range of Change
% of Wall Thickness

FIGURE A - 8

TURKEY POINT 4
S/G A OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Point 219
Average Change -2.23

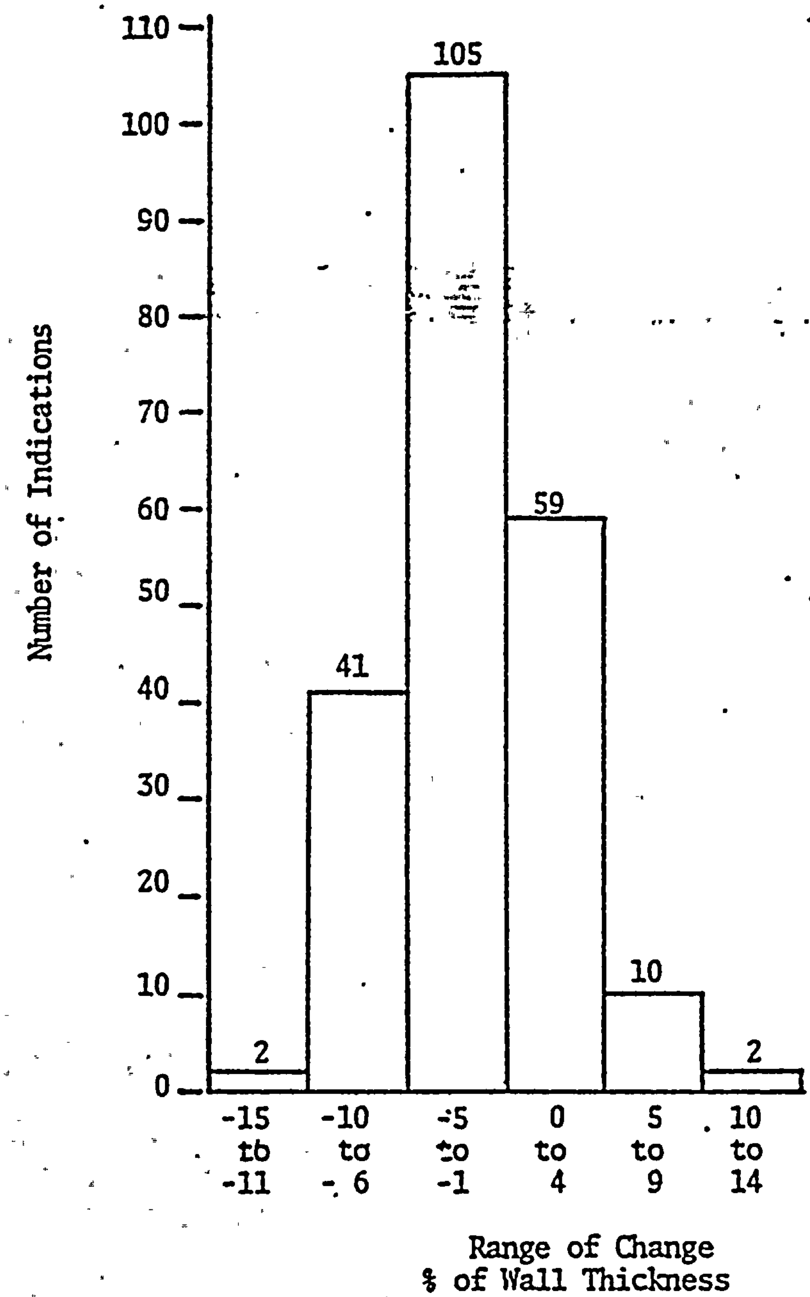


FIGURE A - 9

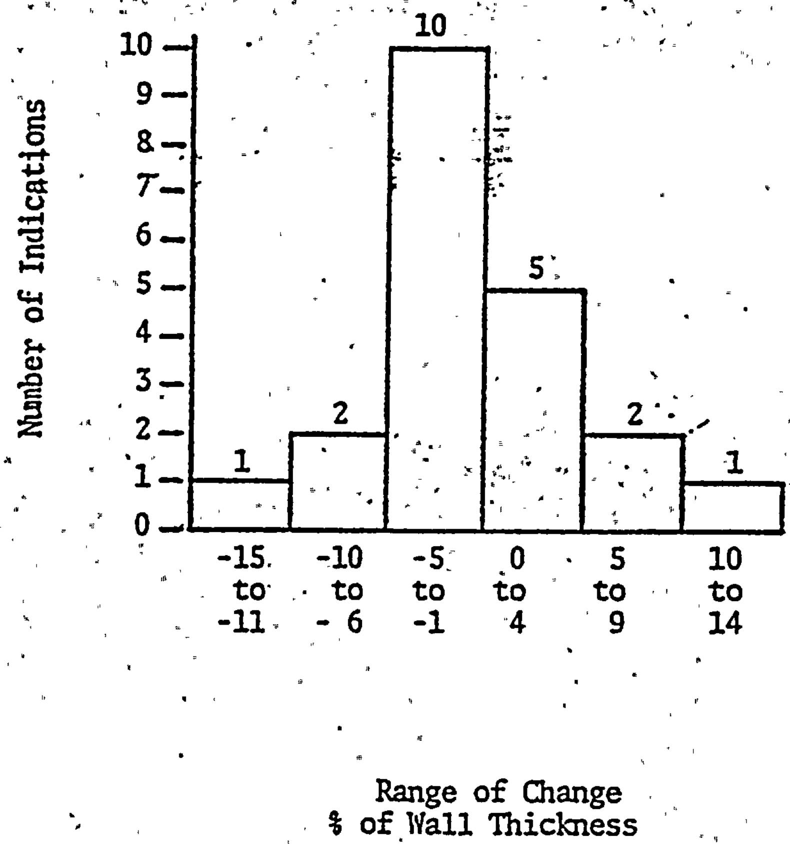
TURKEY POINT 4

S/G B INLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points 21

Average Change -1.14



TURKEY POINT 4

S/G B OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points	46
Average Change	8.41

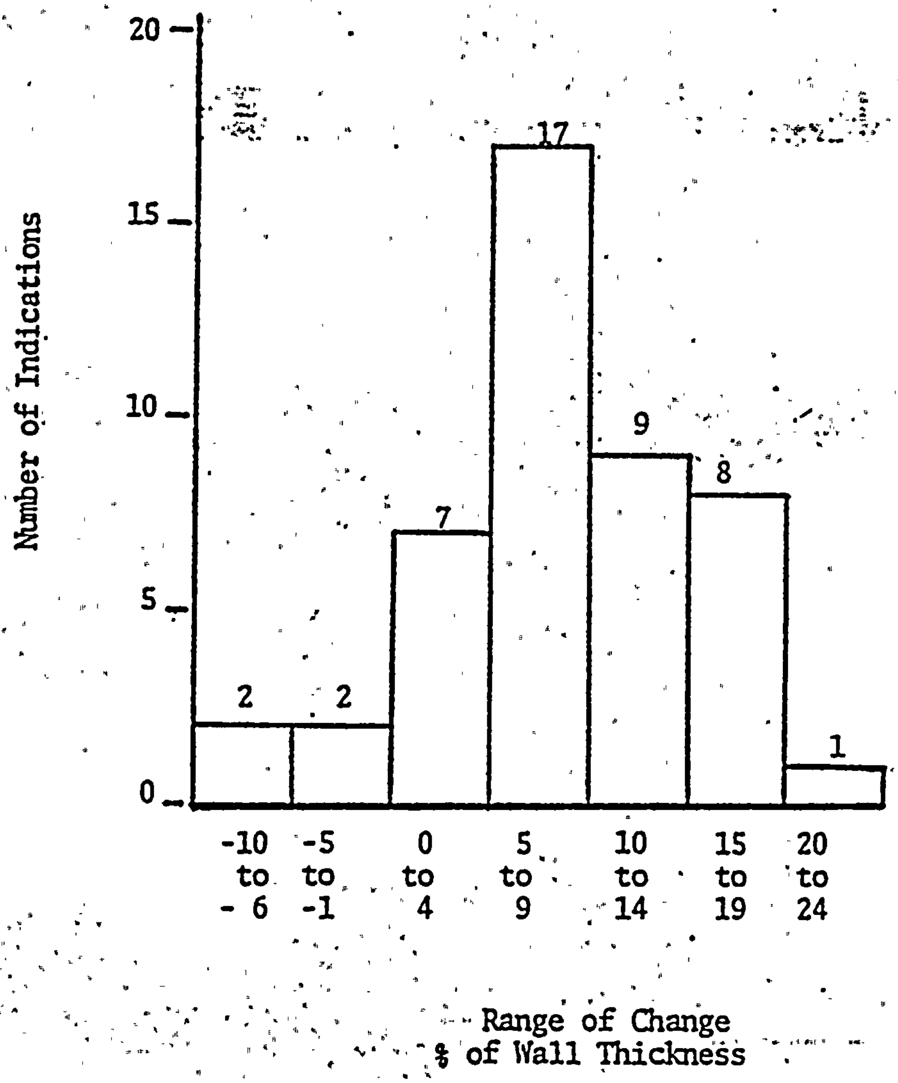


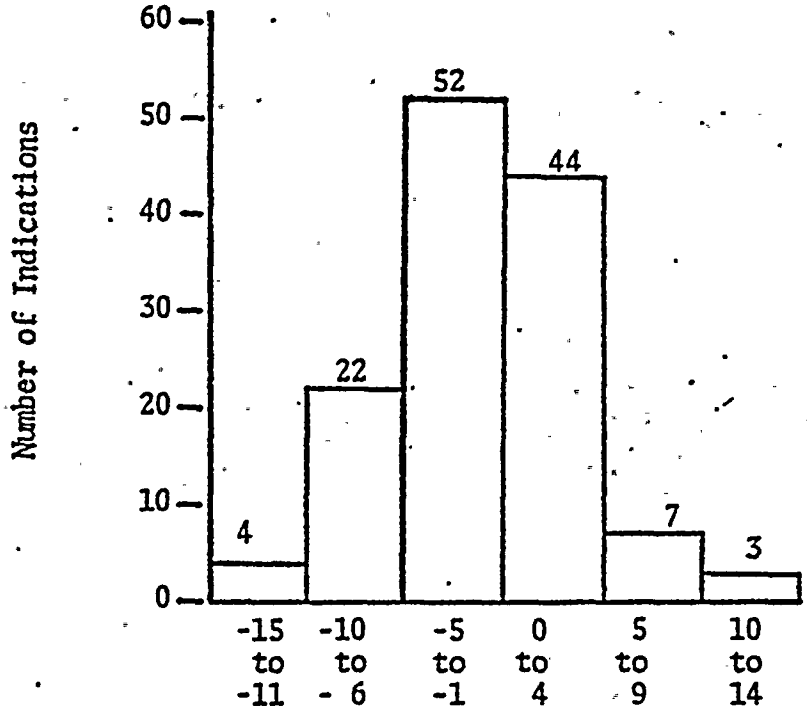
FIGURE A - 11

TURKEY POINT 4

S/G C OUTLET

DISTRIBUTION OF THE CHANGE IN EDDY CURRENT INDICATIONS AT THE TUBESHEET BETWEEN THE MAY 1980 AND NOVEMBER 1980 INSPECTIONS

Total Number of Points	132
Average Change	-1.65



Range of Change
% of Wall Thickness

FIGURES A-12 to A-33

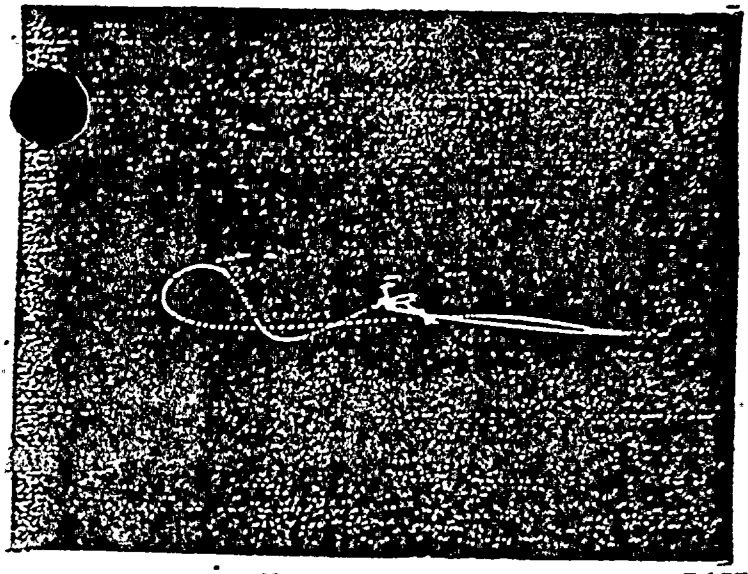
EDDY CURRENT SIGNALS FROM TUBES PLUGGED
IN NOVEMBER, 1980

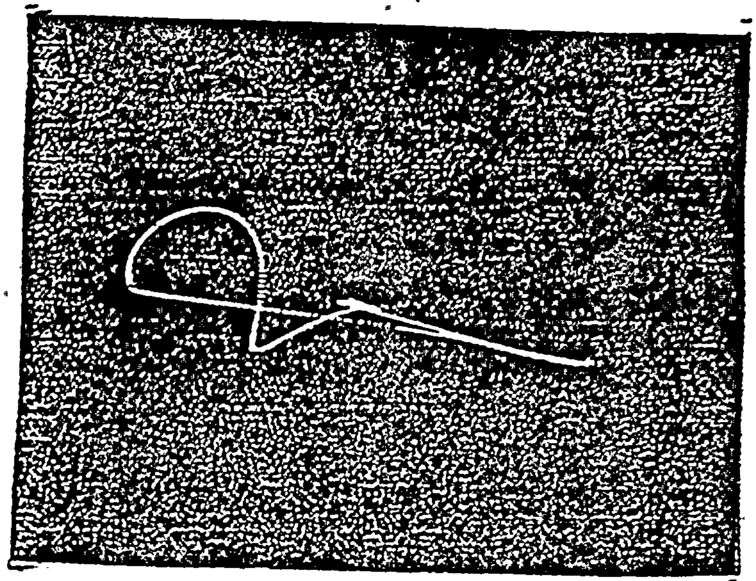
TURKEY POINT UNIT #4

FIG. A-12

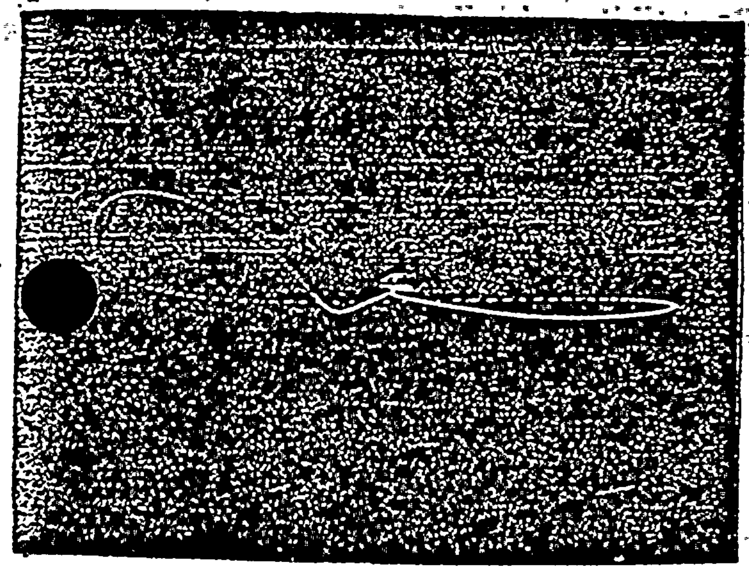
S/G A H.L.

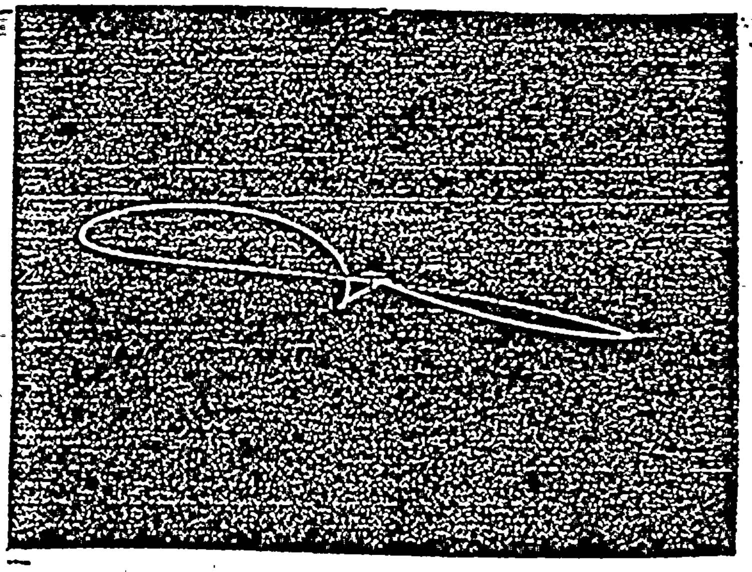
4/79 | 2 VOLTS/DIVISION | 11/80



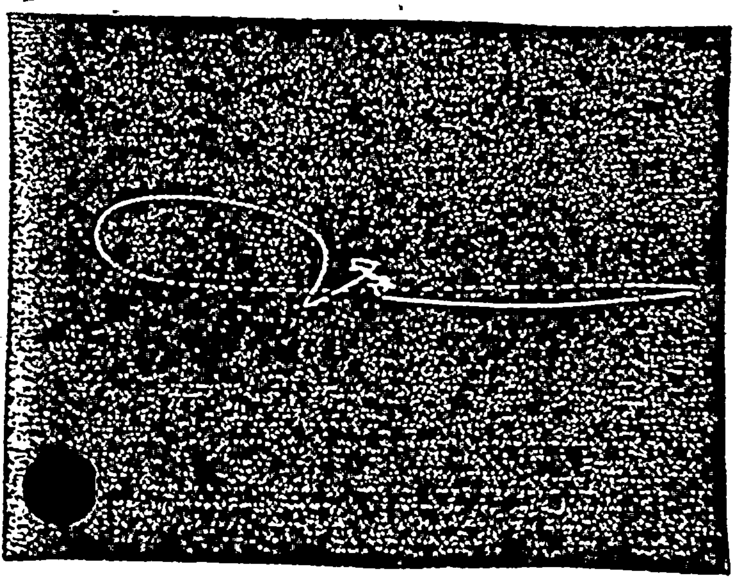


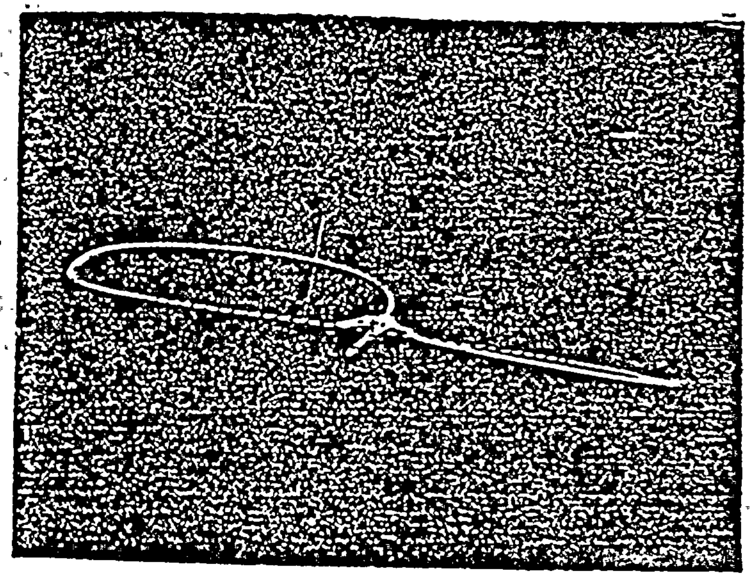
Not Quantified R6C75 62% TTS





Not Quantified R11C22 58% TTS



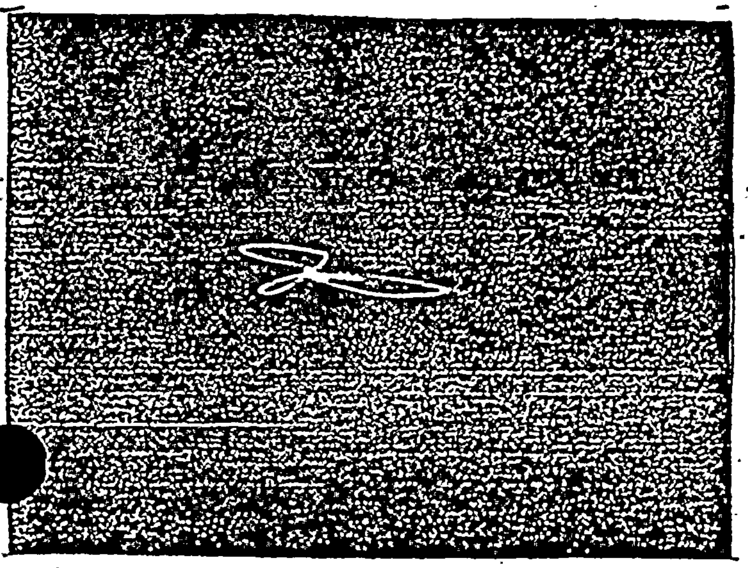


Not Quantified R9C21 45% TTS

TURKEY POINT #4 (FLA)

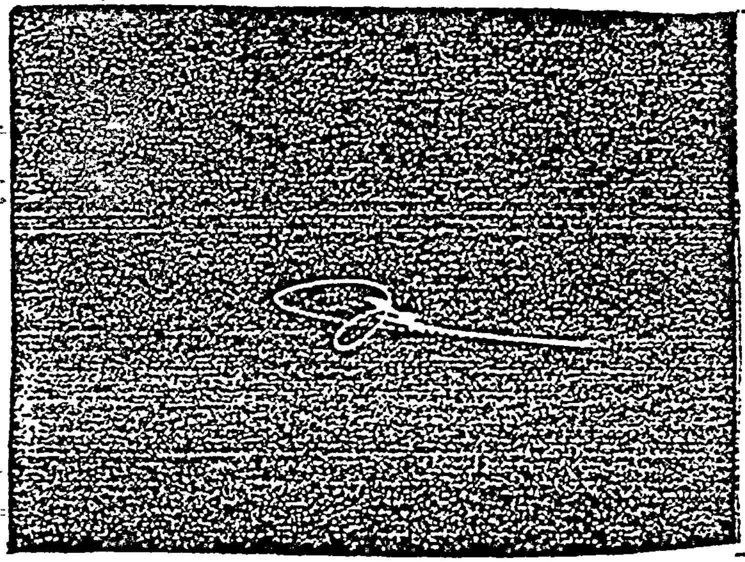
S/G B H.L.
2 VOLTS/DIVISION

4/79



Not Quantified R9C81

11/80



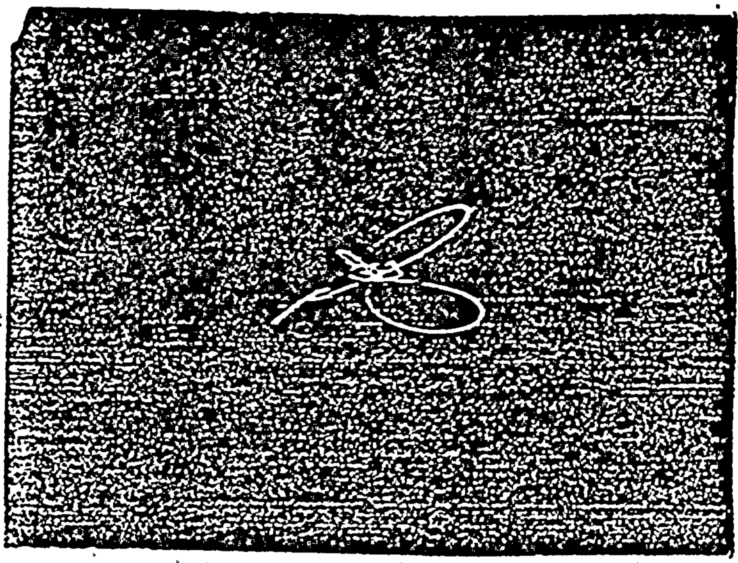
51% 1" ATS

TURKEY POINT #4(FLA)

S/G-B C.L.

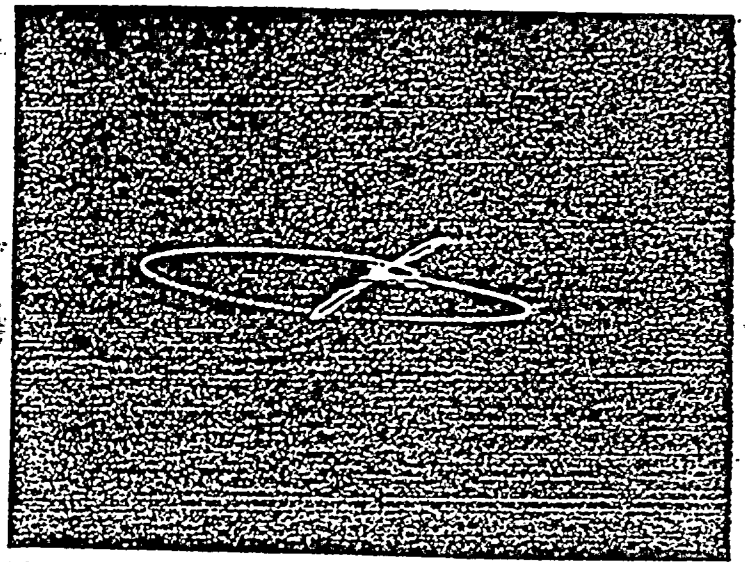
2 Volts/Division

4/79



39%

5/80

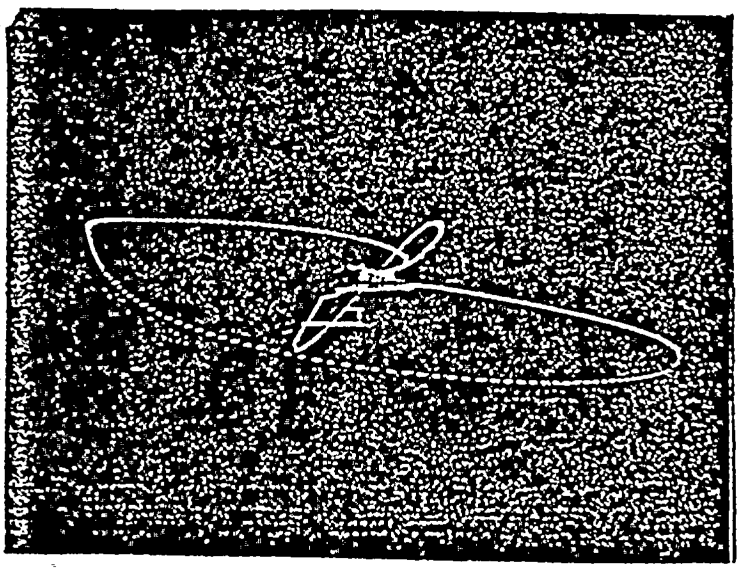


33%

R14C29

2" ATS

11/80



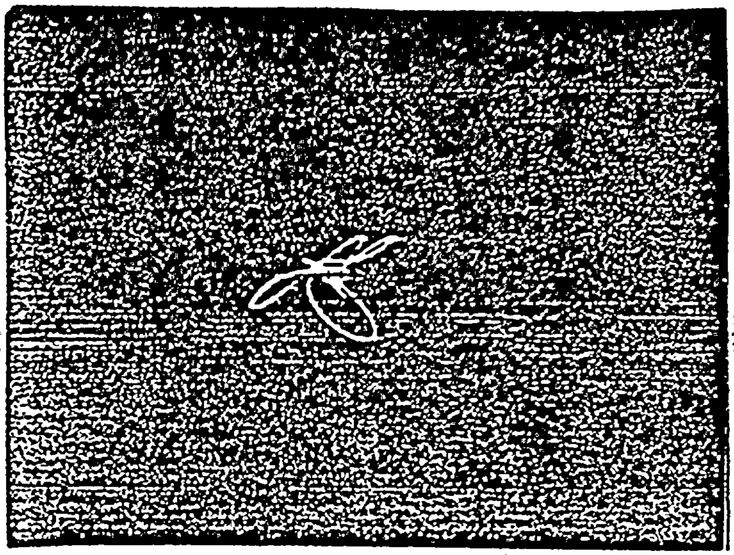
46%

TURKEY POINT #4(FLA)

S/G-B C.L.

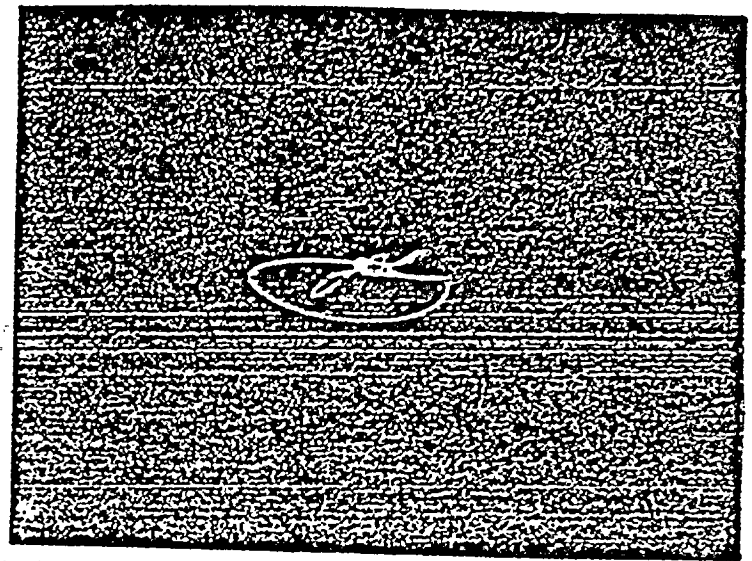
2 Volts/Division

4/79



35%

5/80

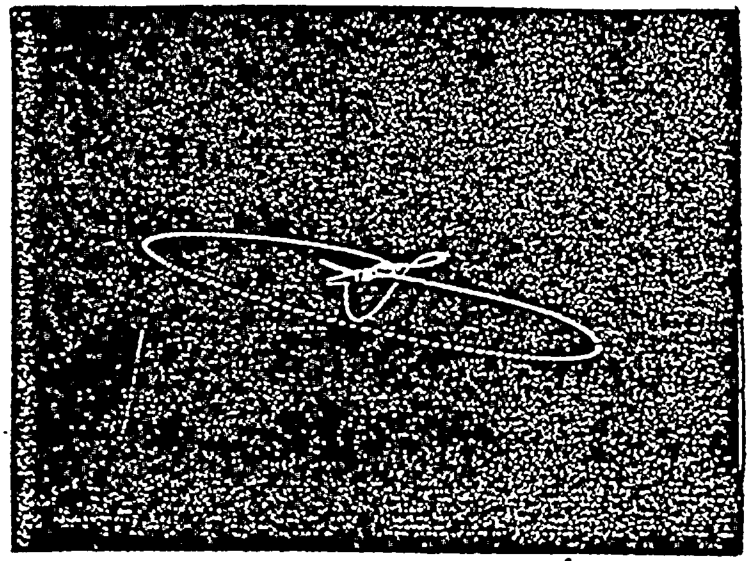


35%

R12C30

2" ATS

11/80



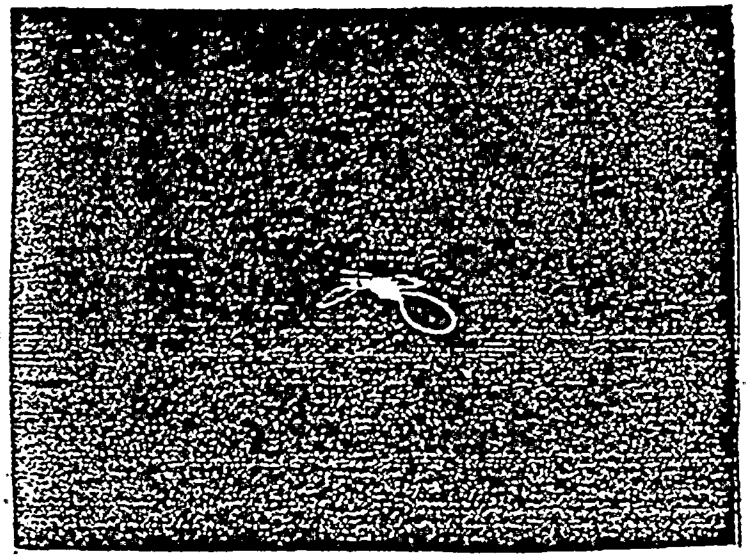
53%

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

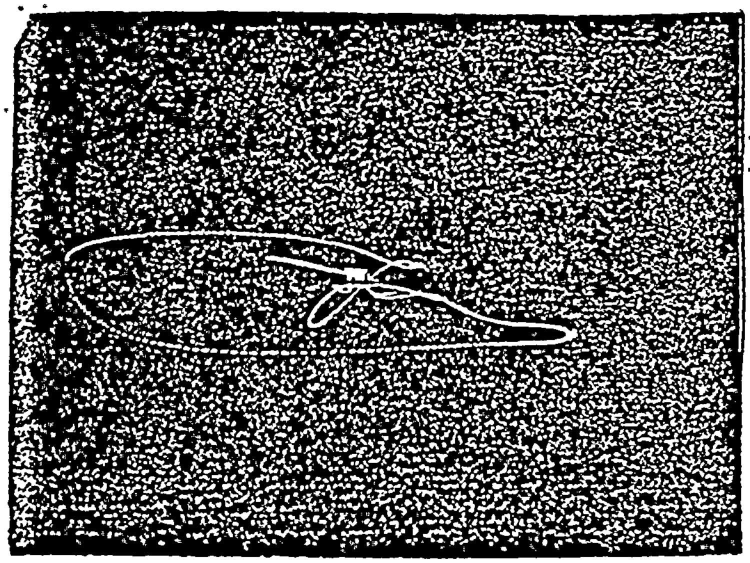
R23C39

2" ATS

5/80

Not Tested

11/80



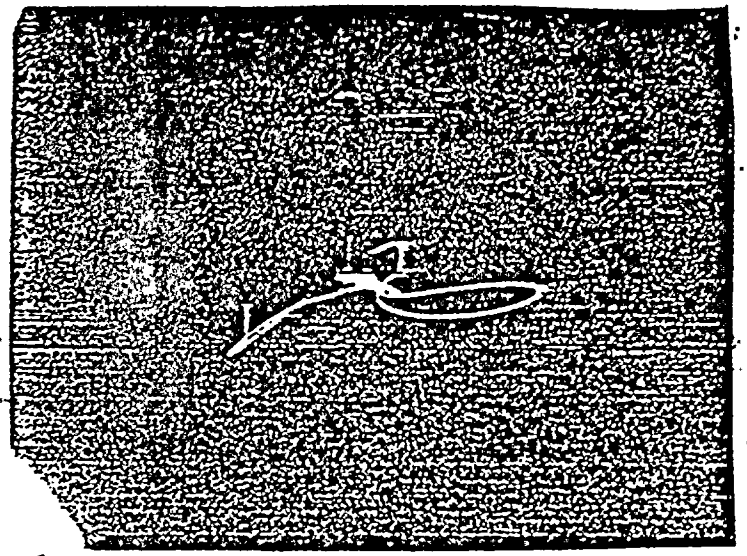
43%

TURKEY POINT #4 (FL_

S/G-B C.L.

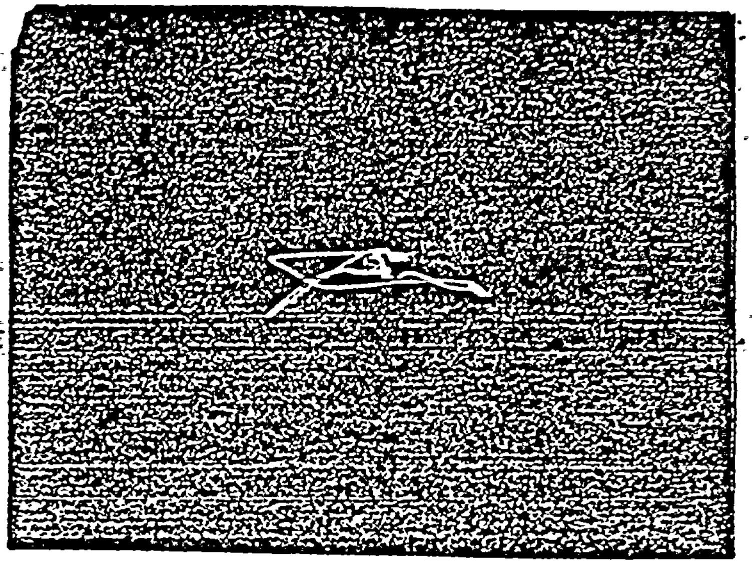
2 Volts/Division

4/79



38%

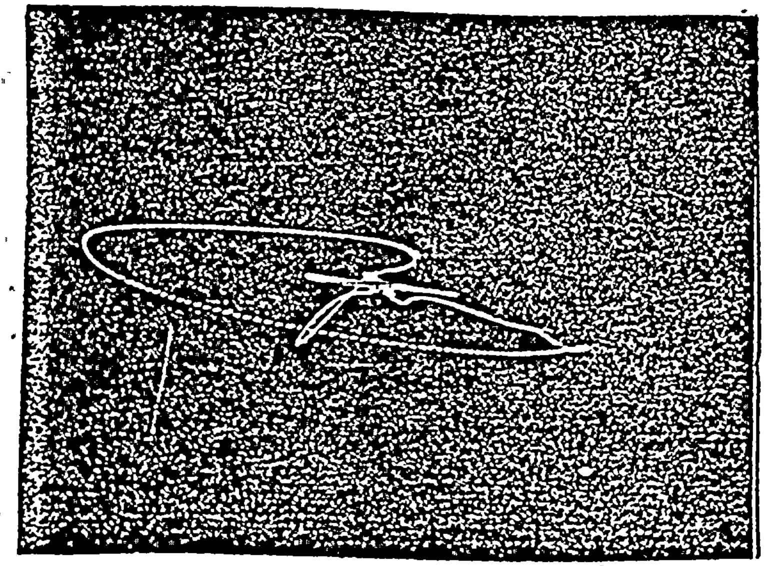
5/80



31 %

R24C39

1" ATS



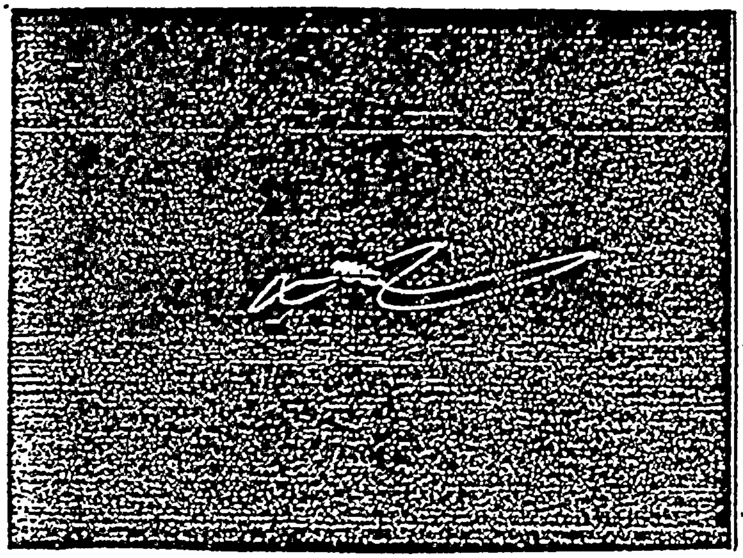
44%

TURKEY POINT #4(FLA)

S/G-B C.L.

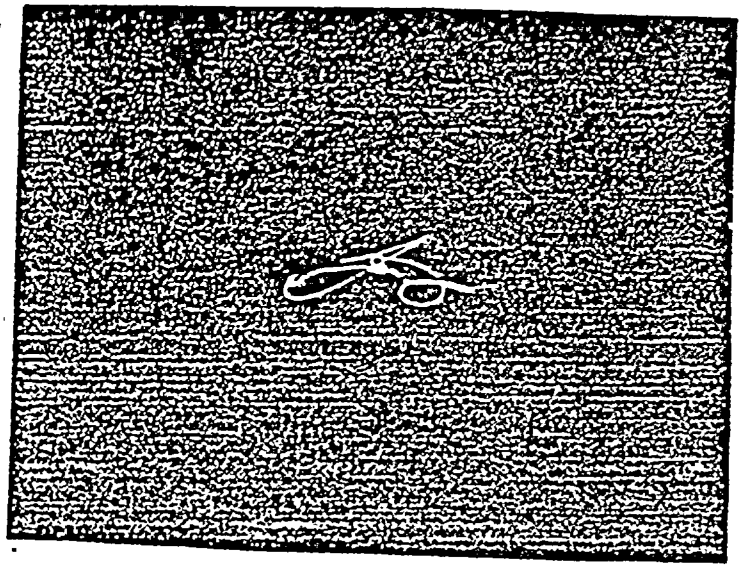
2 Volts/Division

4/79



< 20%

5/80

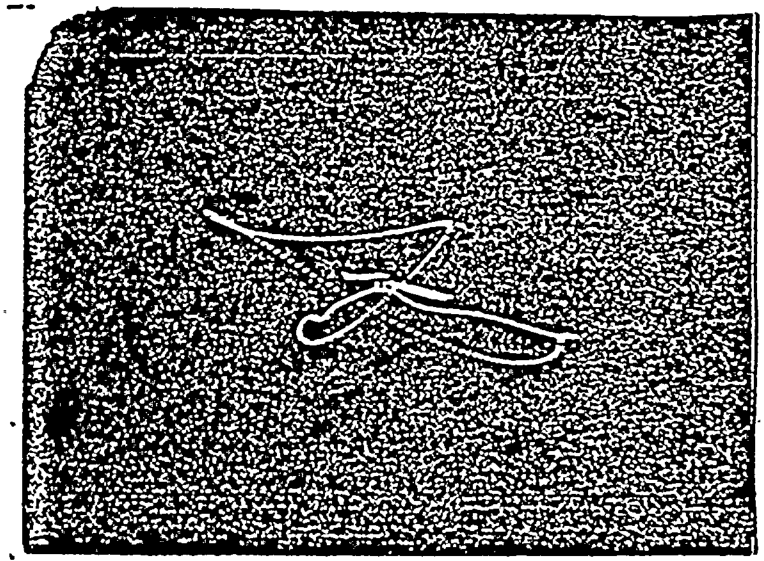


24%

R24C40

½" ATS

11/80



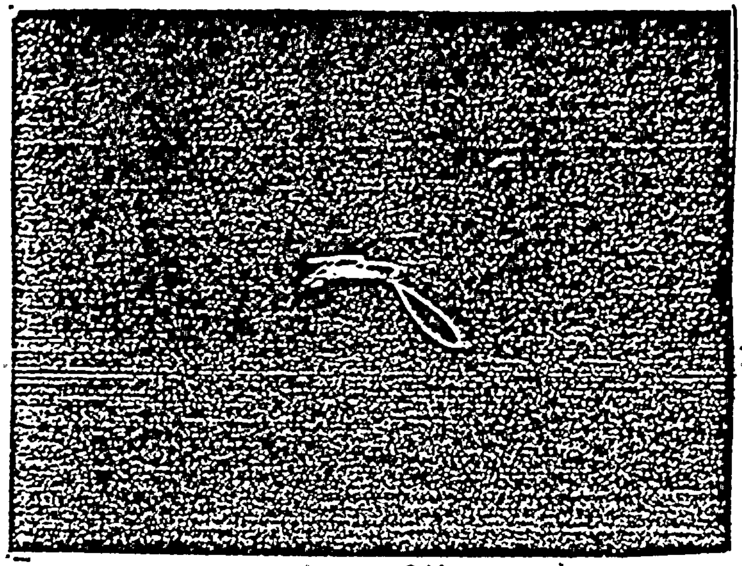
41%

TURKEY POINT #4 (FLA)

S/G-B C.L.

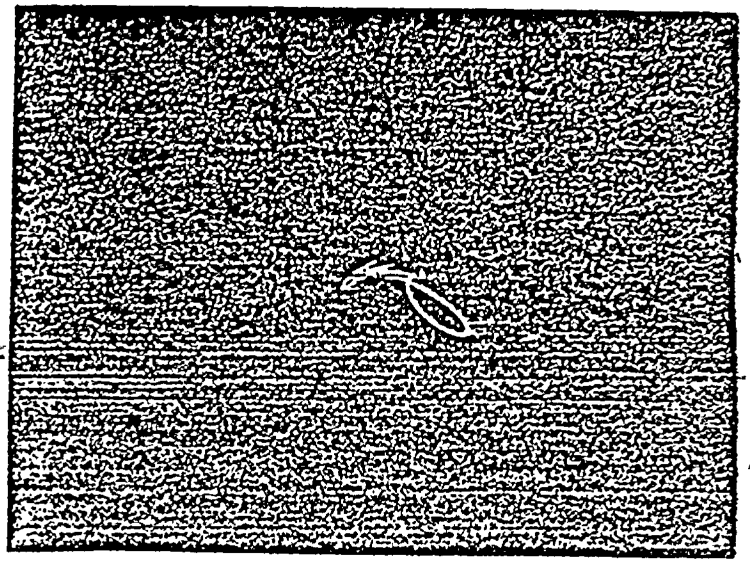
2 Volts/Division

4/79



24%

5/80

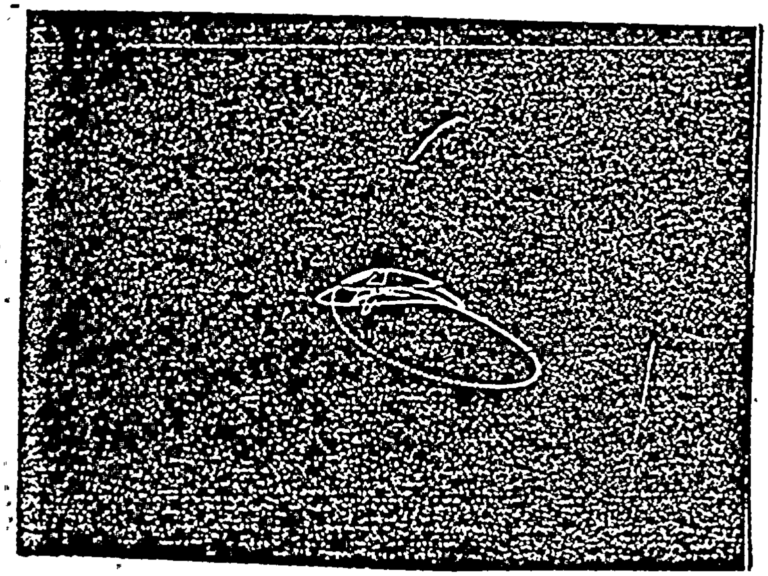


36%

R11C44

2" ATS.

11/80



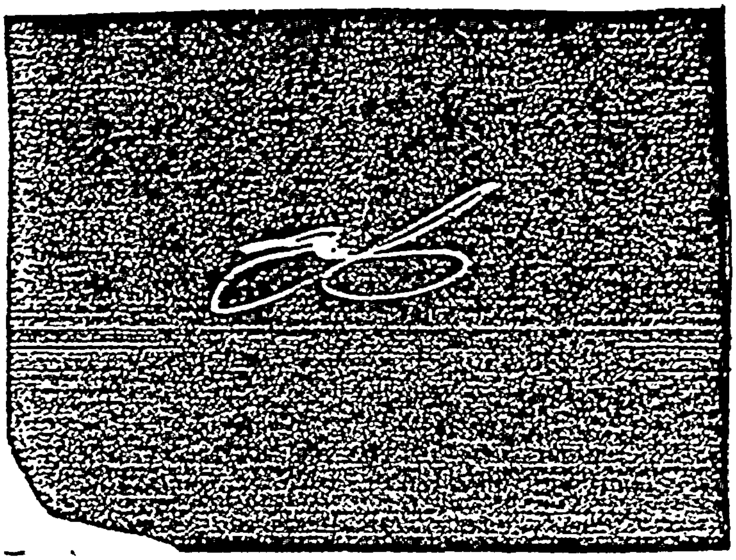
53%

TURKEY POINT #4 (FLA)

S/G-B C.L.

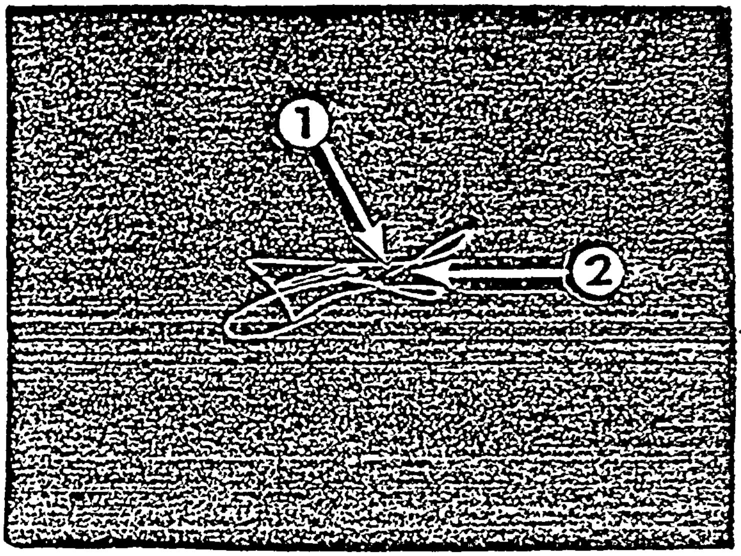
2 Volts/Division

4/79



28%

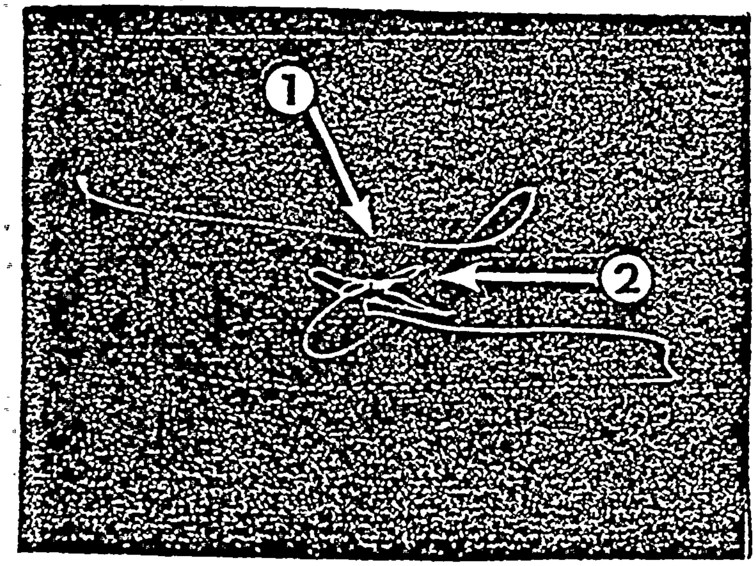
5/80



28%

R22C44
1" ATS

11/80



45%

FIG. A-21

TURKEY POINT #4(FLA)

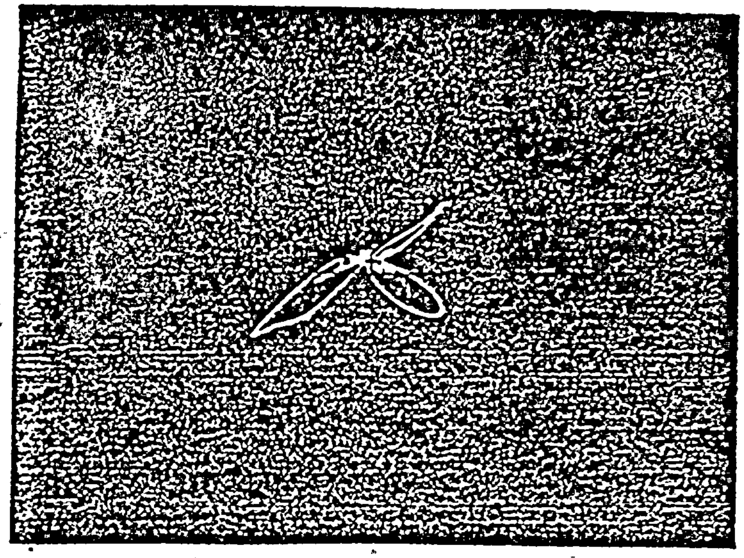
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

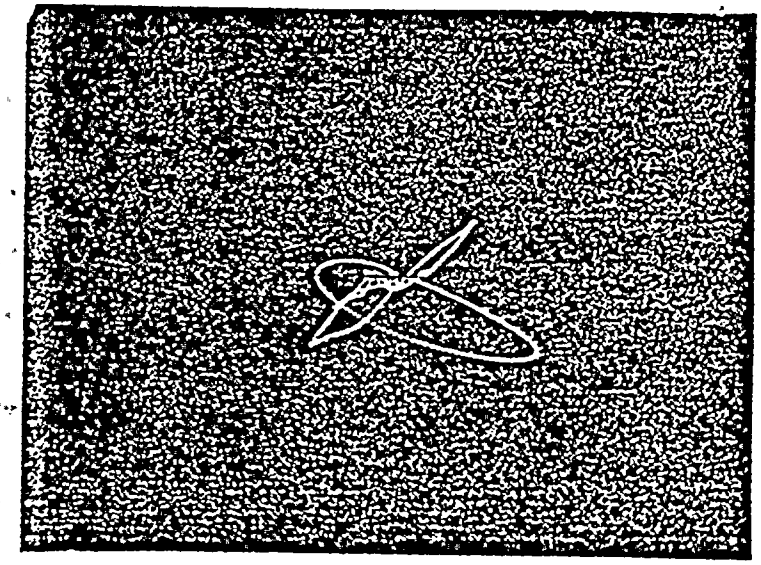
5/80



R10C46 37%

2" ATS

11/80



45%

TURKEY POINT #4(FLA)

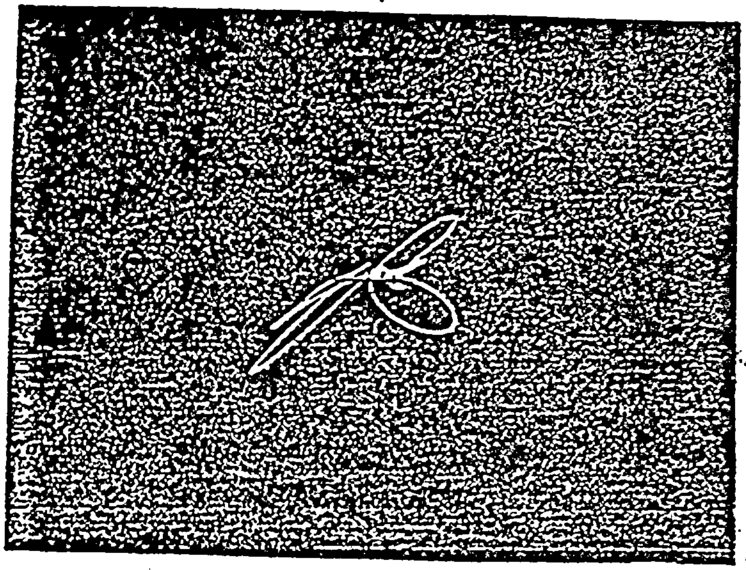
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

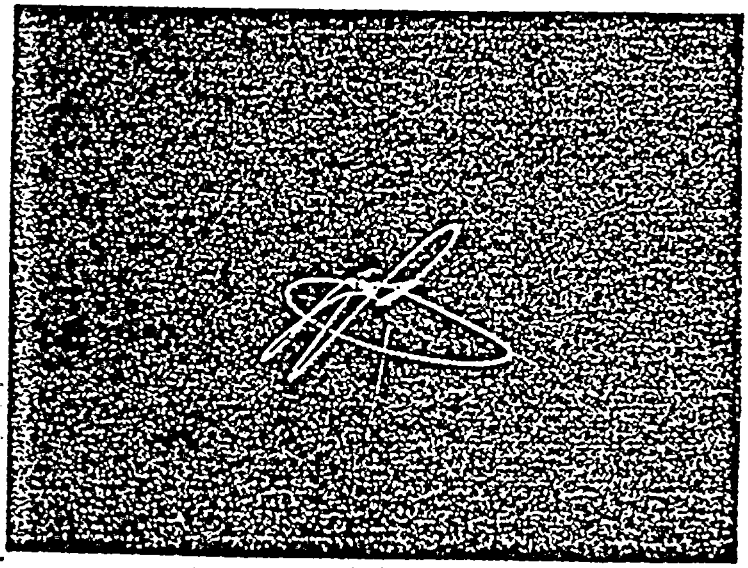
5/80



R11C46 39%

2" ATS

11/80



43%

TURKEY POINT #4 (FLA)

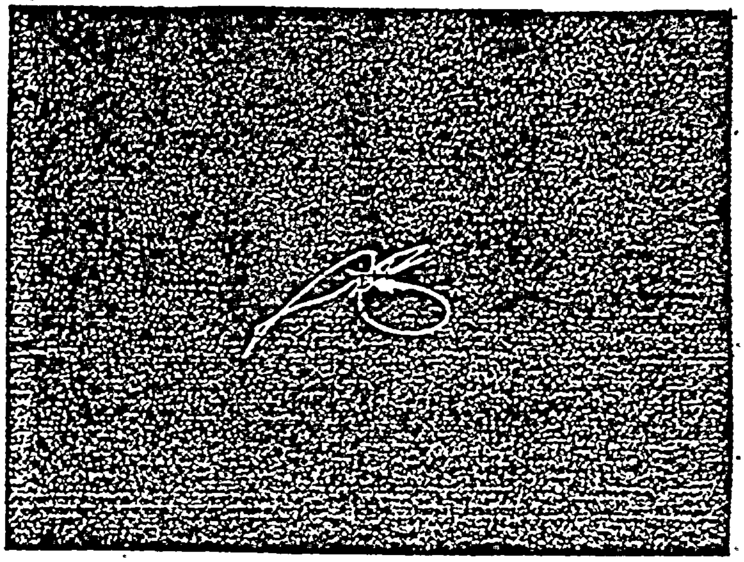
S/G-B C.L.

2 Volts/Division

4/79

NOT TESTED

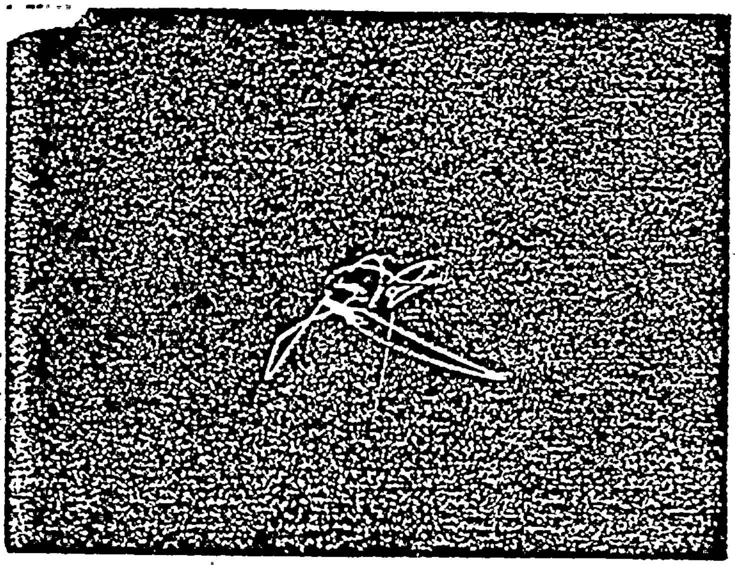
5/80



R13C46
3" ATS

33%

11/80



51%

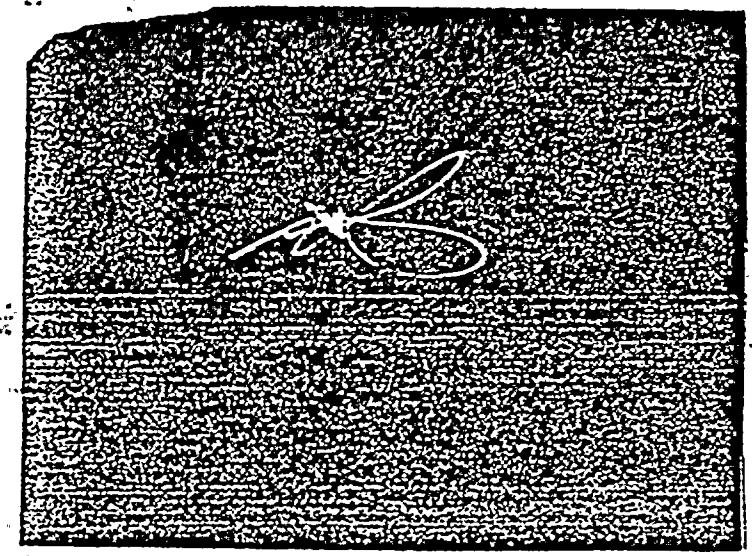
FIG. A-24

TURKEY POINT #4(FLA)

S/G-B C.L.

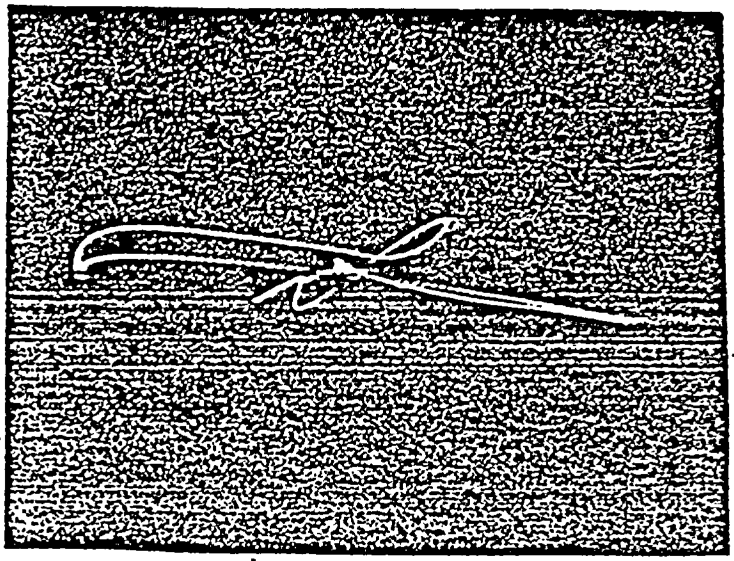
2 Volts/Division

4/79



32%

5/80

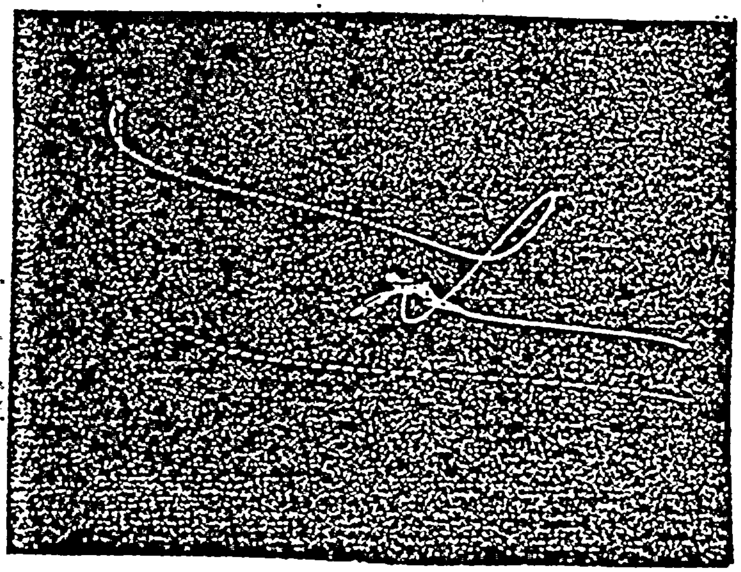


32%

R22C46

½" ATS

11/80



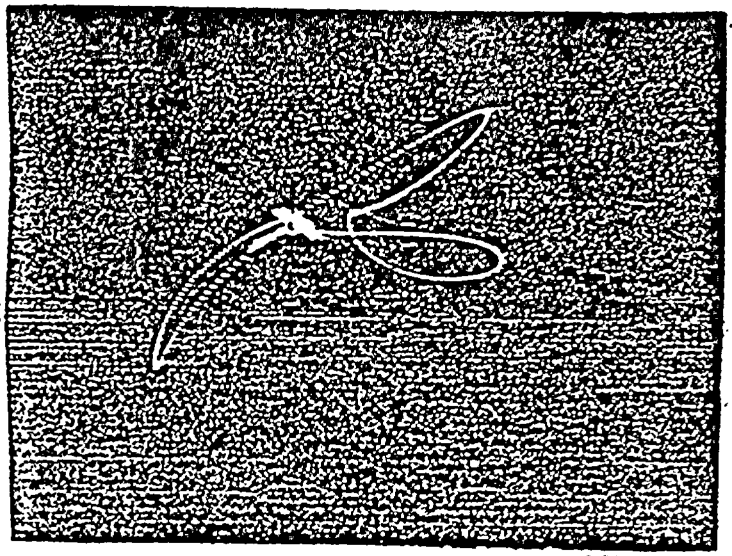
49%

TURKEY POINT #4(FLA)

S/G-B C.L.

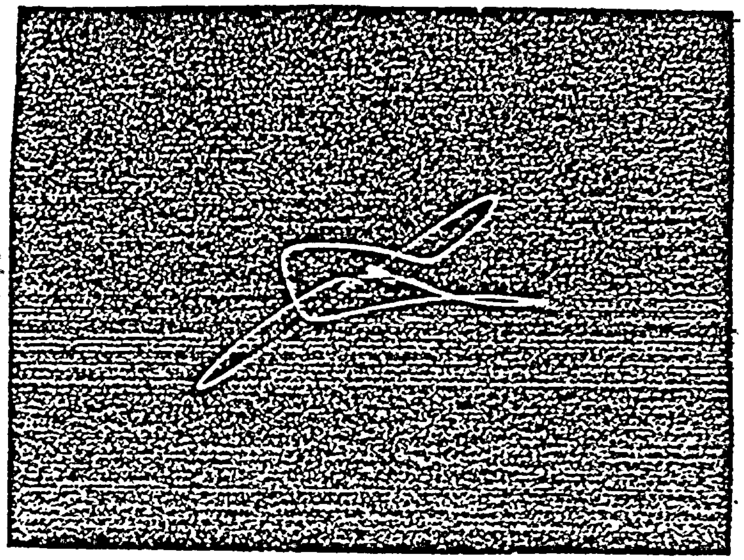
2 Volts/Division

4/79



35%

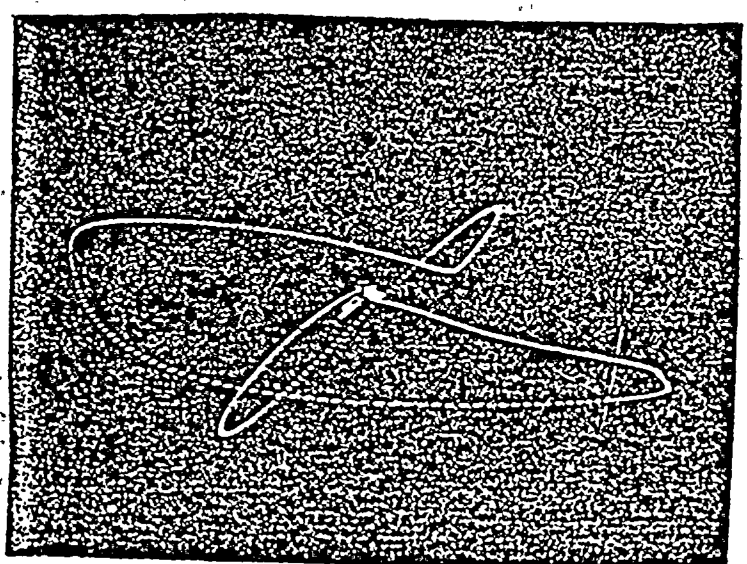
5/80



32%

R23C46
1" ATS

11/80



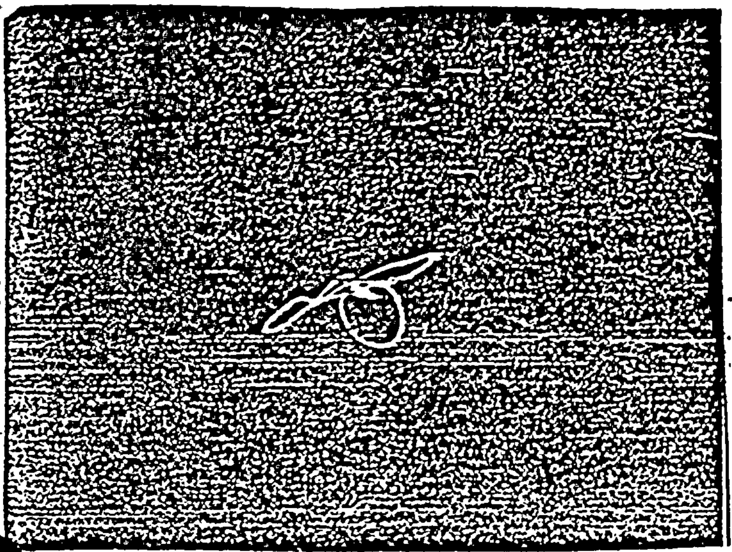
41%

TURKEY POINT #4(FLA) FIG. A-26

S/G-B C.L.

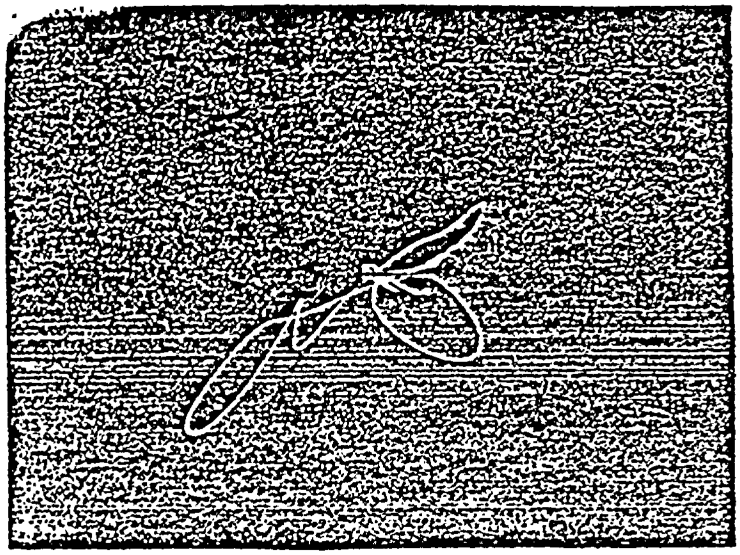
2 Volts/Division

4/79



22%

5/80

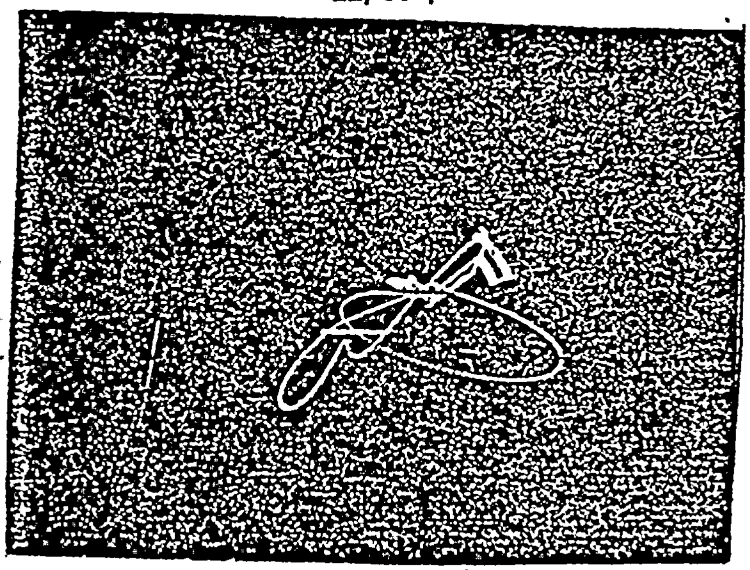


39%

R10C47

3" ATS

11/80



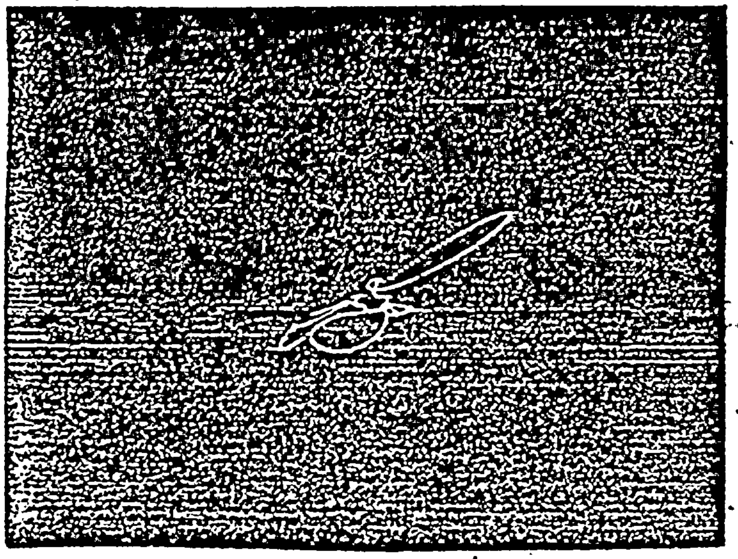
47%

TURKEY POINT #4(FLA)

S/G-B C.L.

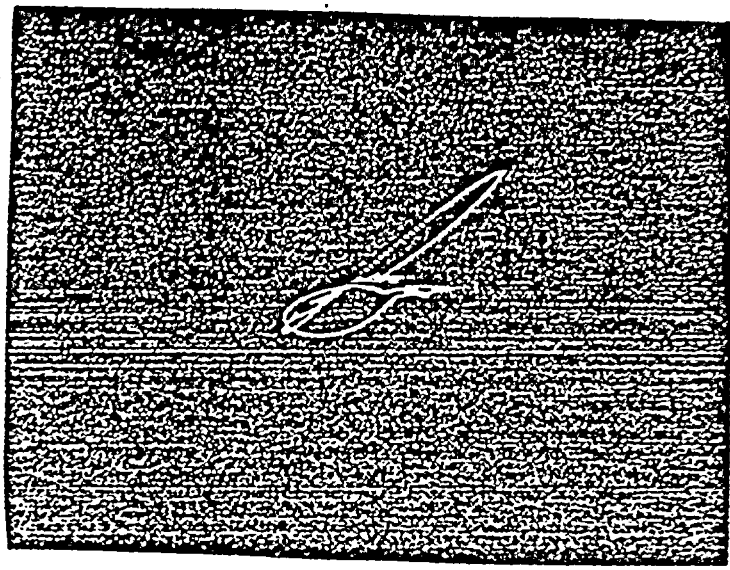
2 Volts/Division

4/79



31%

5/80

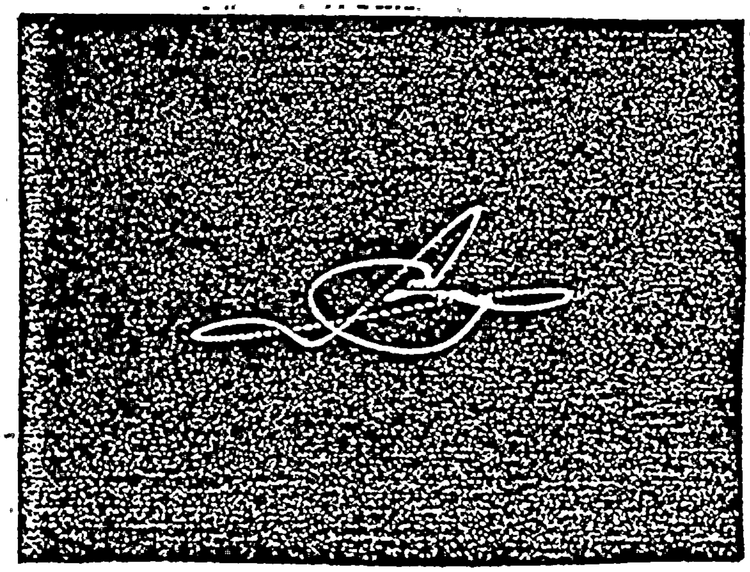


37%

R7C62

2" ATS

11/80

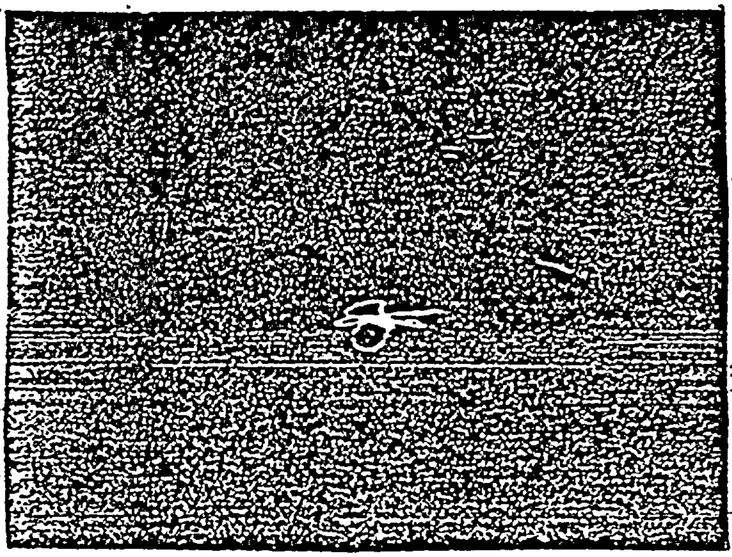


42%

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

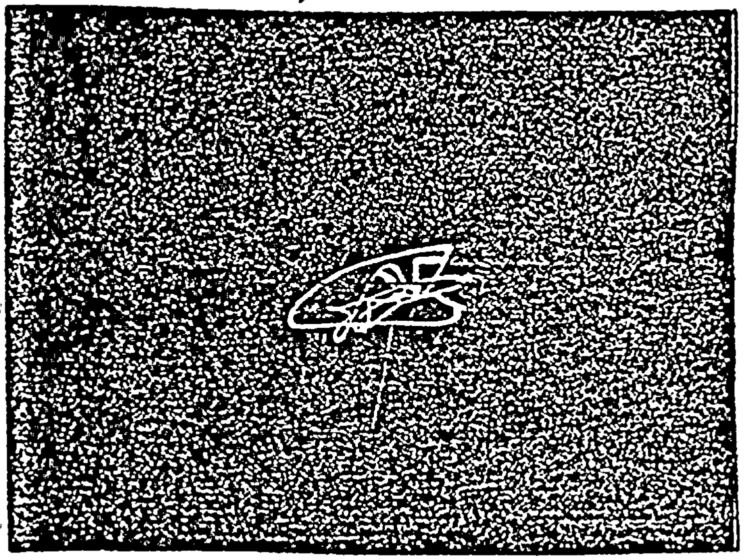
5/80

Not Tested

R7C64

2" ATS

11/80



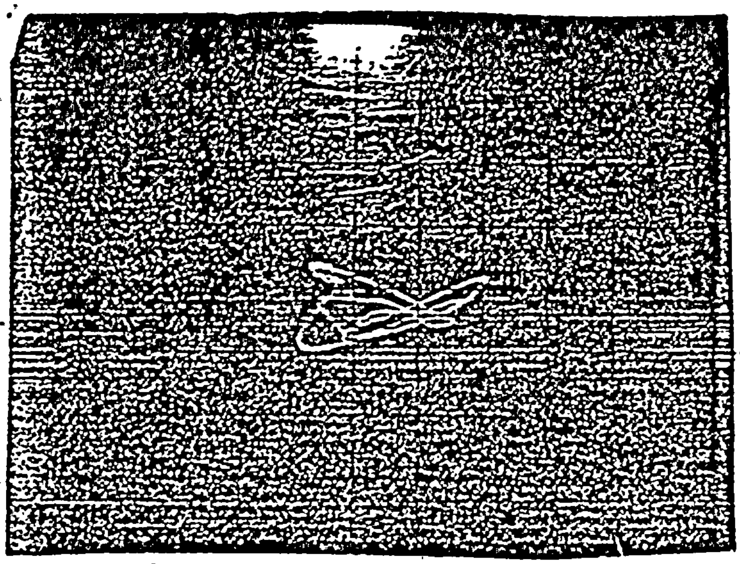
57%

TURKEY POINT #4(FLA)

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

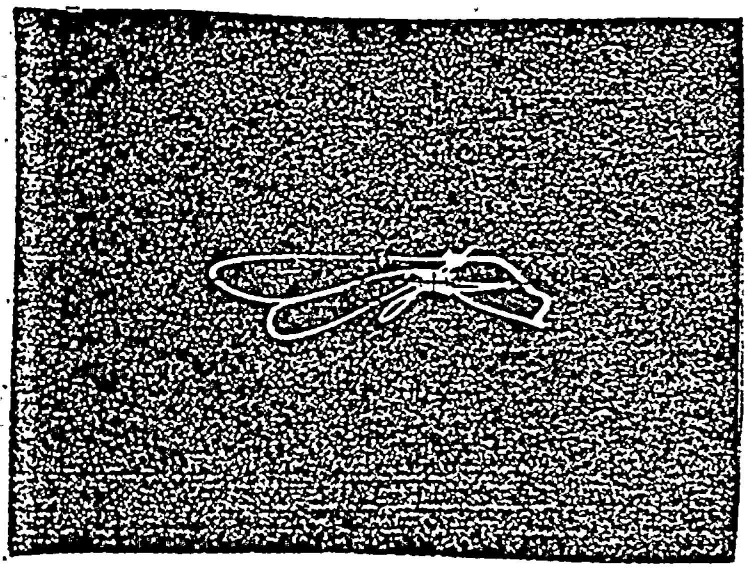
5/80

Not Tested

R7C65

3" ATS

11/80



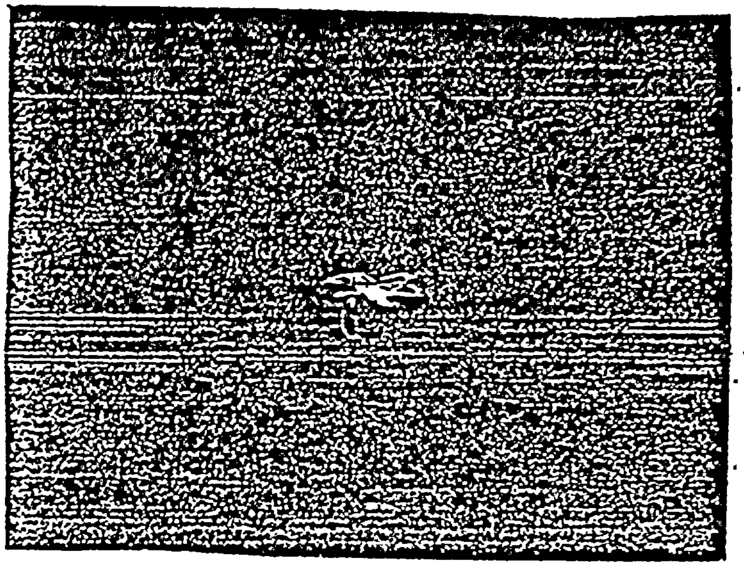
42%

TURKEY POINT #4(FLA)

S/G-B C.L.

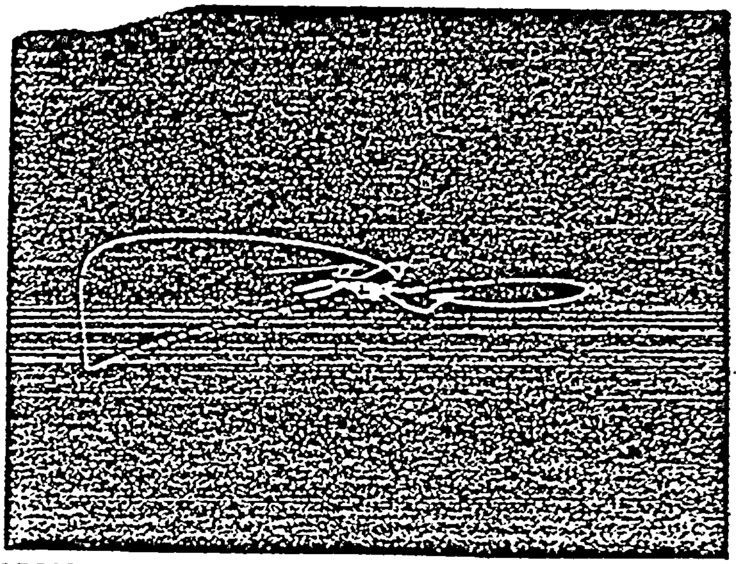
2 Volts/Division

4/79



20%

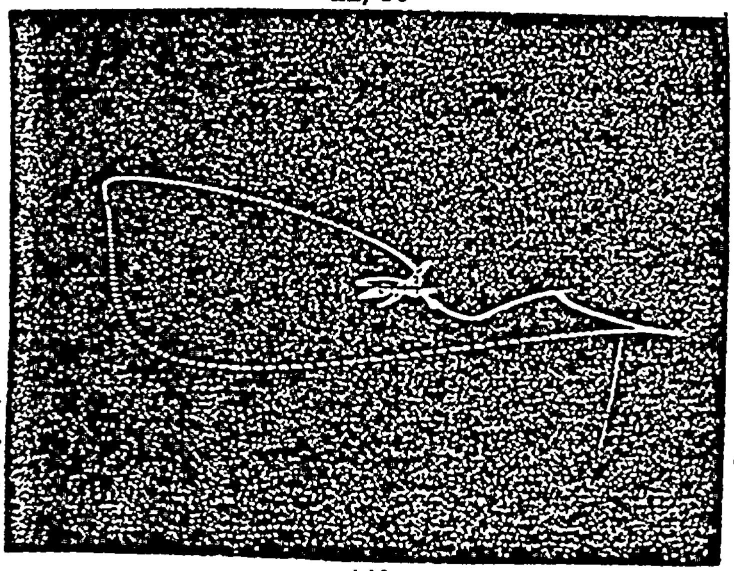
5/80



22%

R17C69
3" ATS

11/80



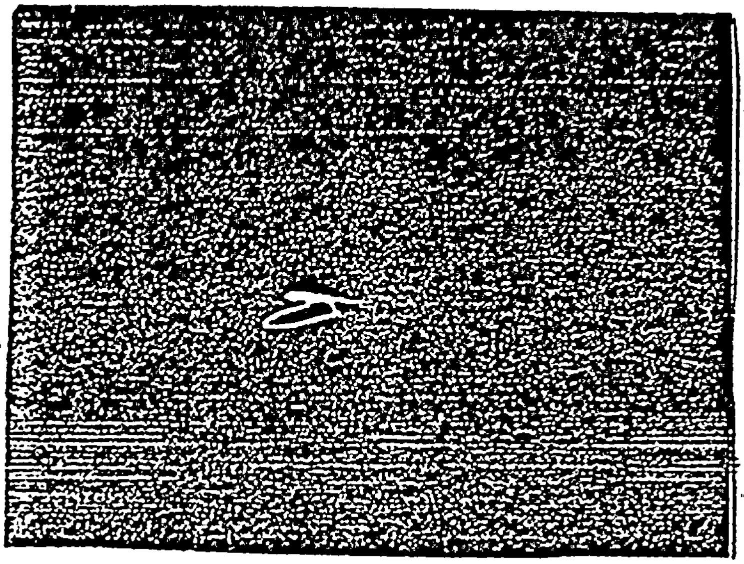
44%

TURKEY POINT #4(FLA)

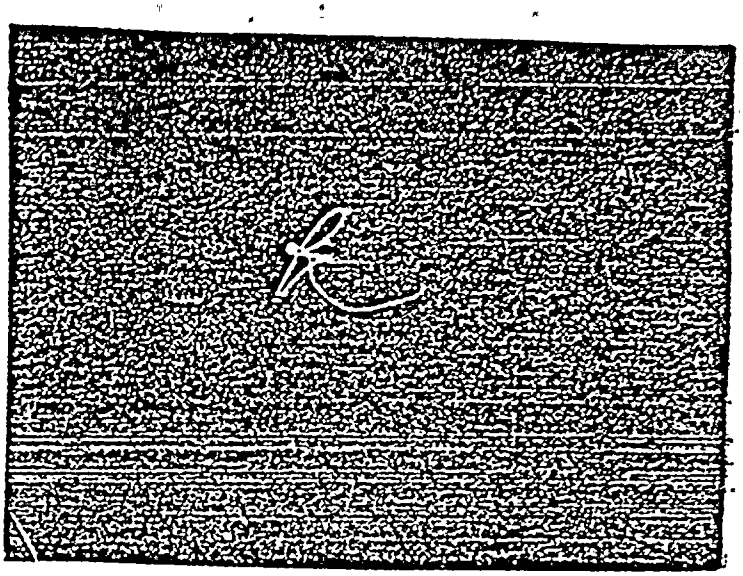
S/G-C H.L.

2 Volts/Division

4/79



11/80

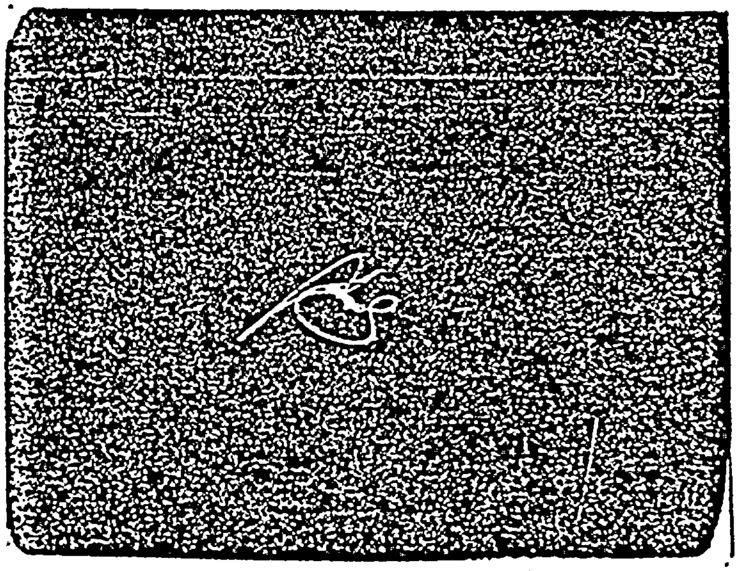


Not Quantified

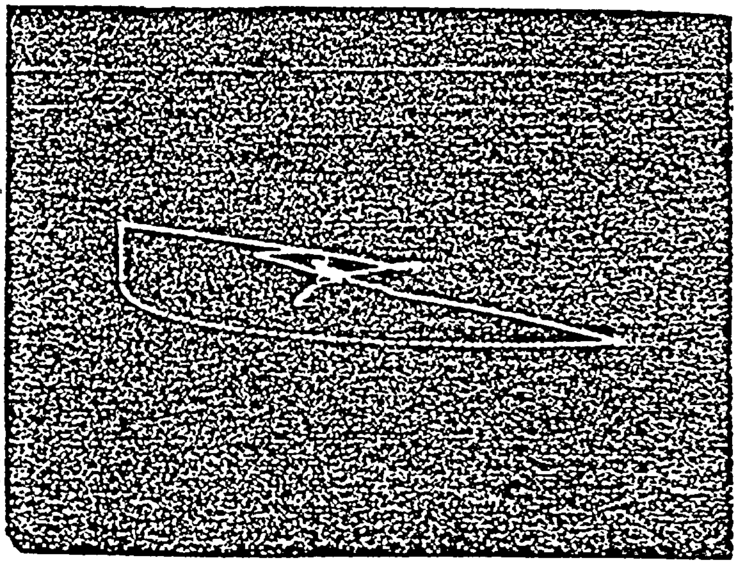
R44C53
1" ATS

51%

5/75



11/80



36%

R14C53
2" ATS

49%

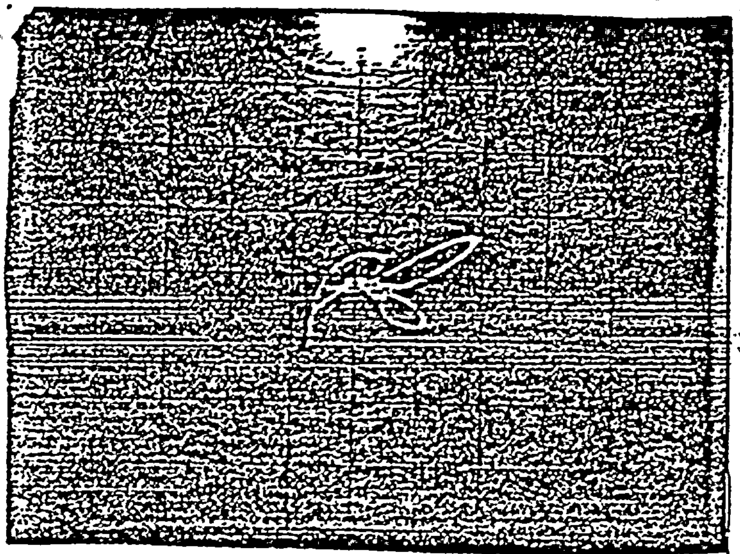
TURKEY POINT #4(FLA)

S/G-C C.L.

2 Volts/Division

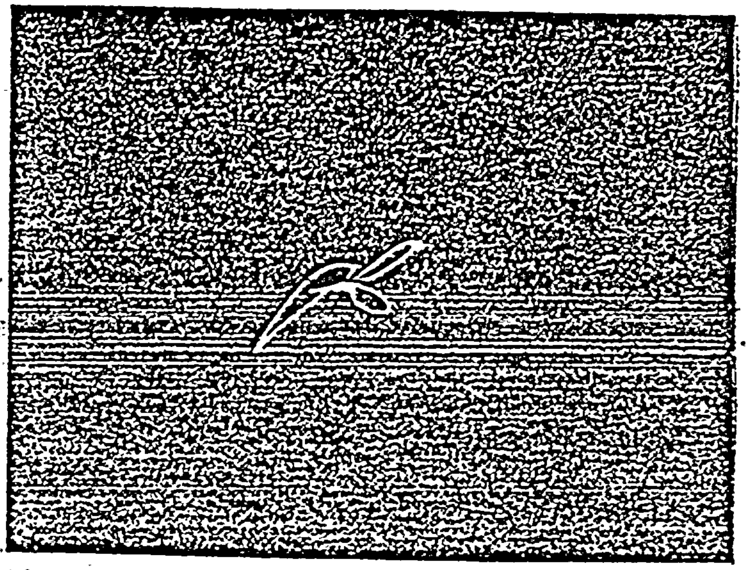
FIG. A-32

4/79



31%

5/80

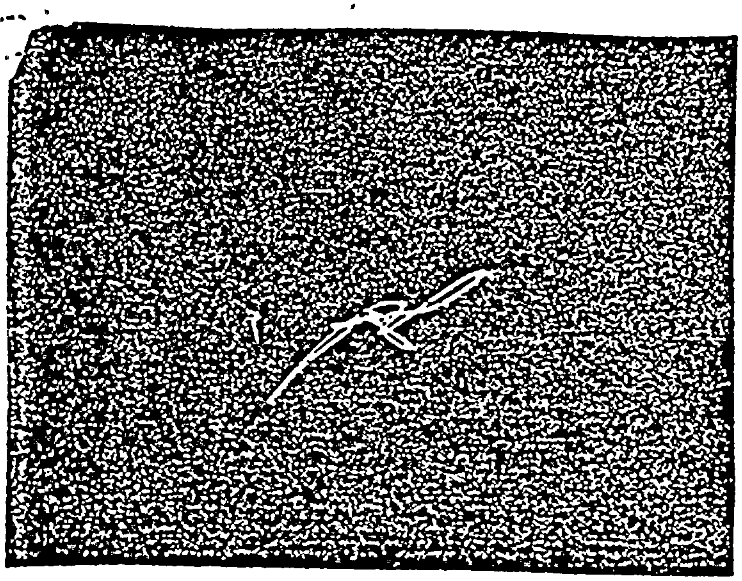


31%

R10C46

2" ATS

11/80



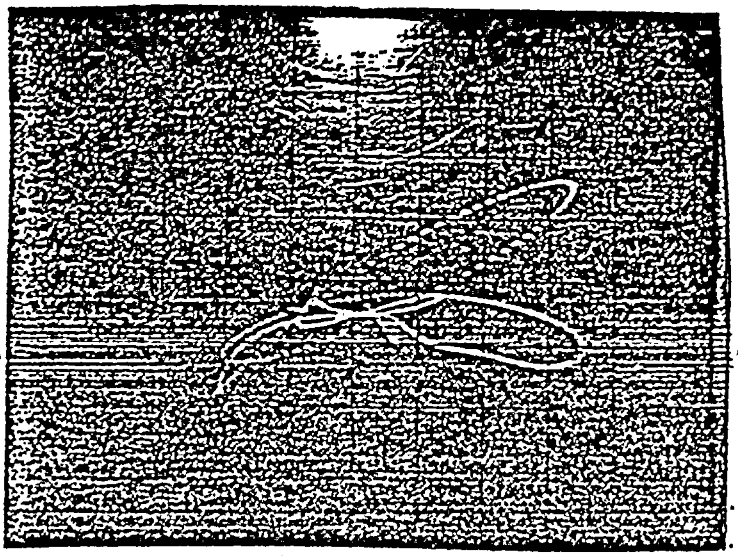
44%

TURKEY POINT #4 (FLA)

S/G-C C.L.

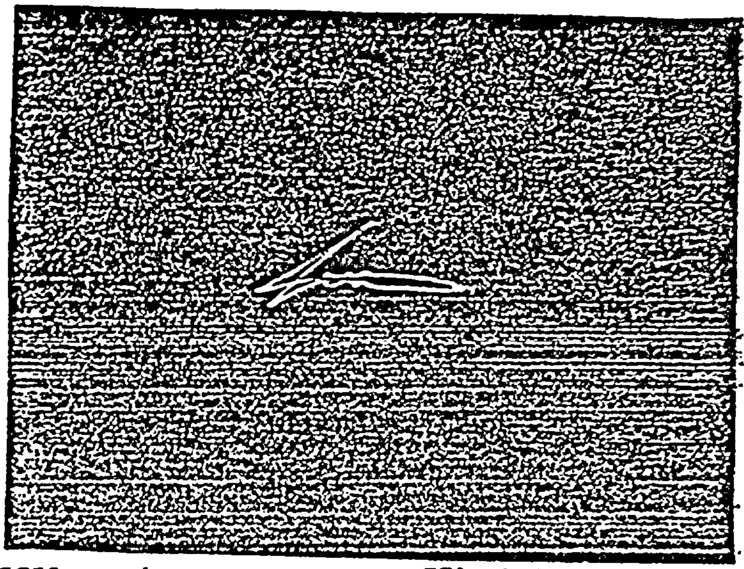
2 Volts/Division

4/79



30%

5/80

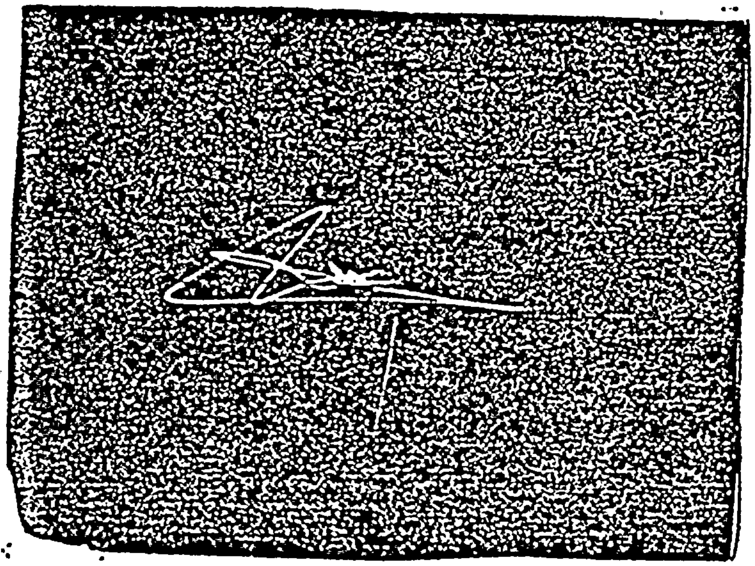


33%

R5C58

TTS

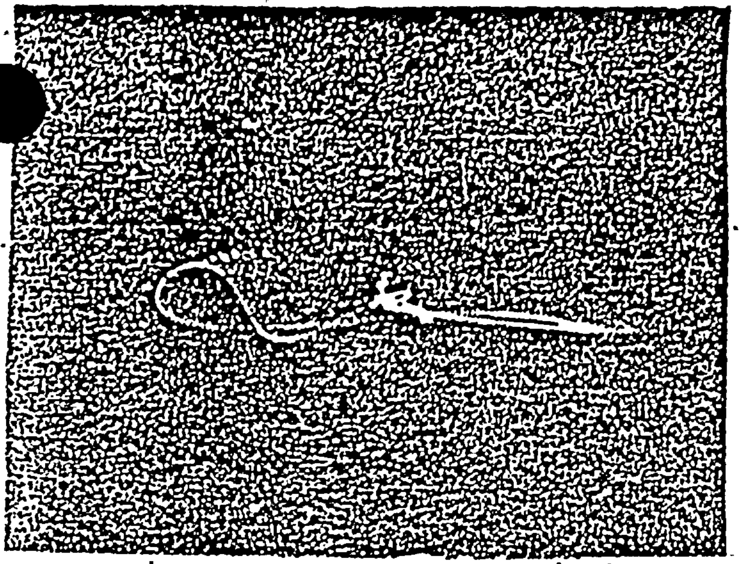
11/80

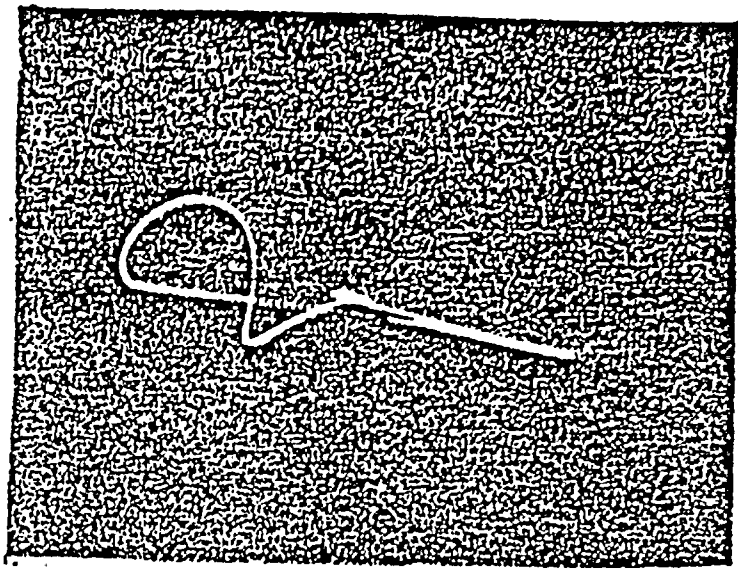


44%

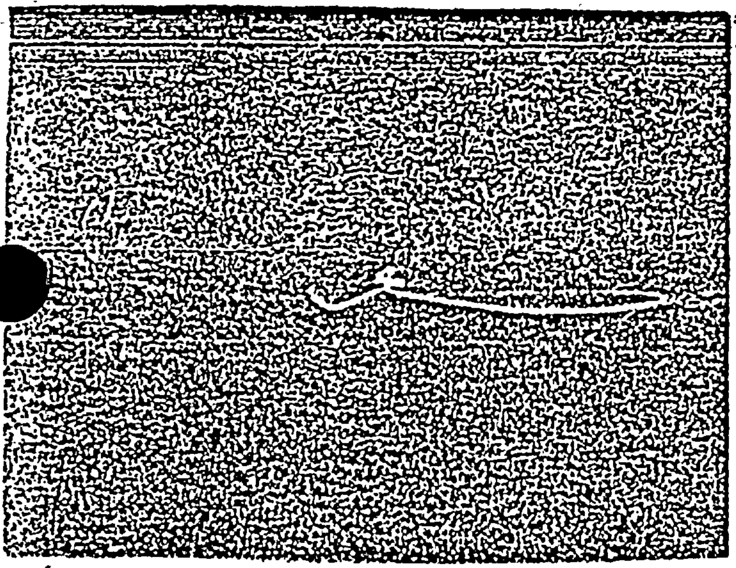
S/G A H.L.

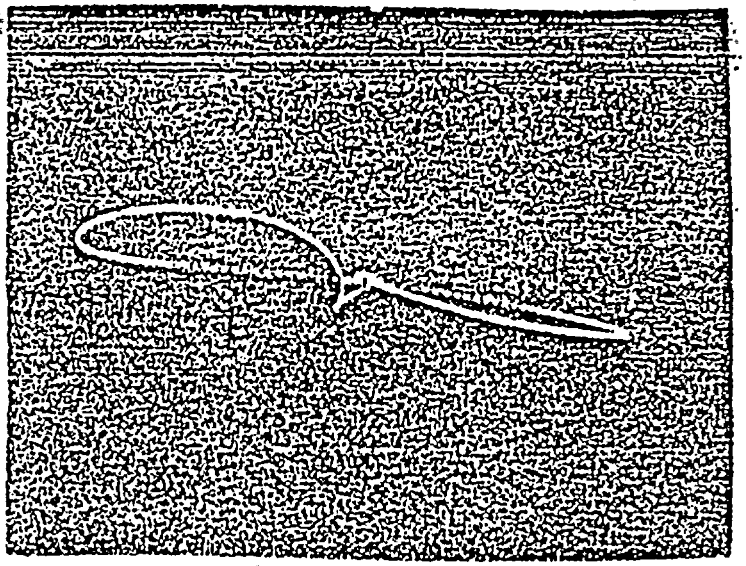
4/79 2 VOLTS/DIVISION 11/80



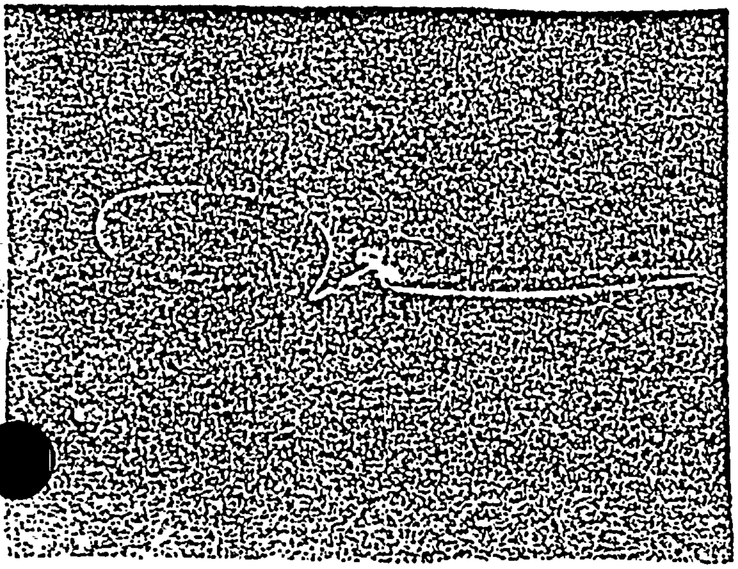


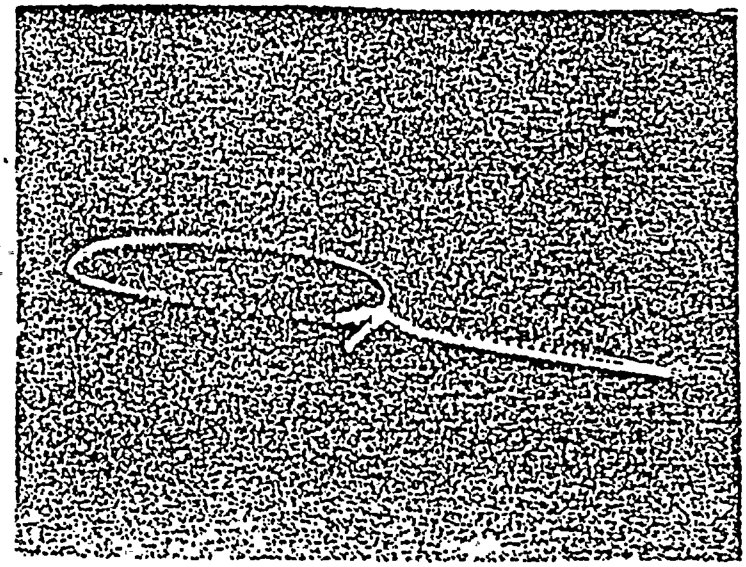
Not Quantified R6C75 [illegible]% TTS





Not Quantified R11C22 58% TTS



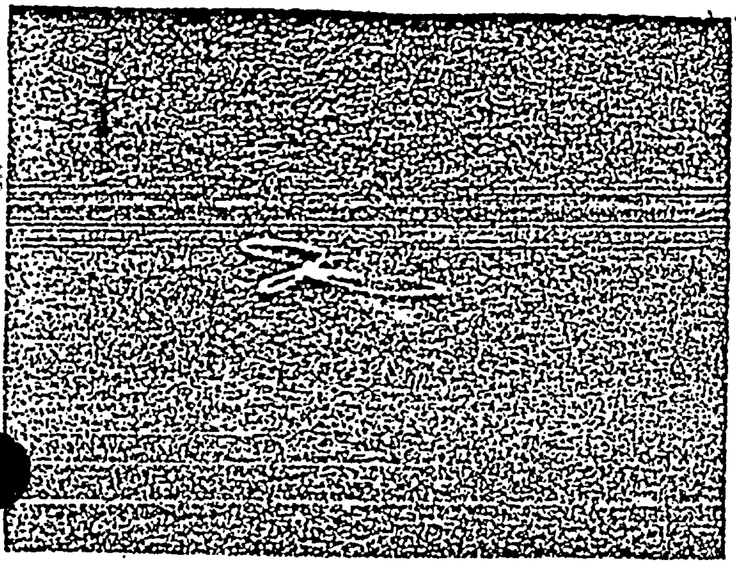


Not Quantified [illegible]C21 [illegible]% TTS

TURKEY POINT #4 (FLA)

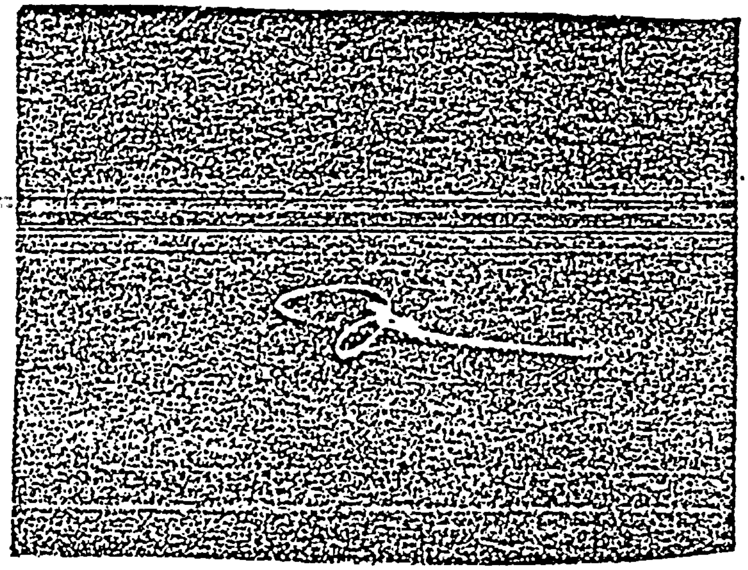
S/G B H.L.
2 VOLTS/DIVISION

4/79



Not Quantified R9C81

11/80



51% 1" ATS

TURKEY POINT #4(FLA)

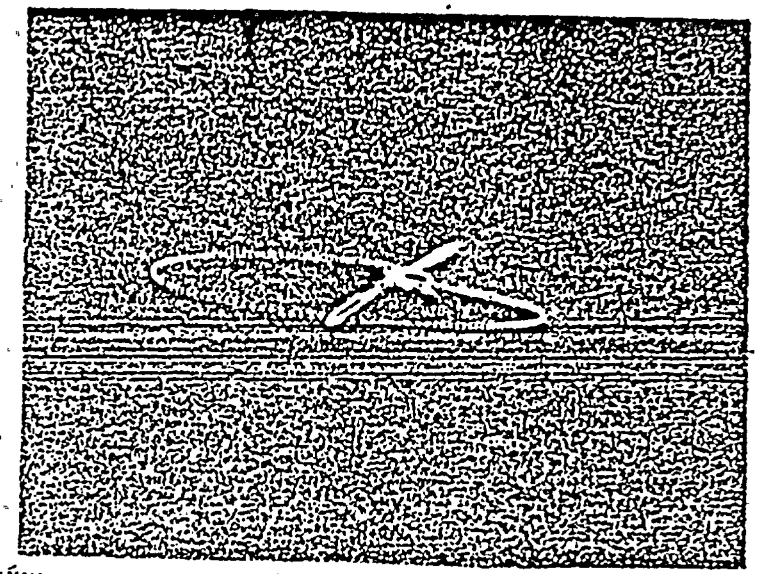
S/G-B C.L.

2 Volts/Division

4/79

59%

5/80

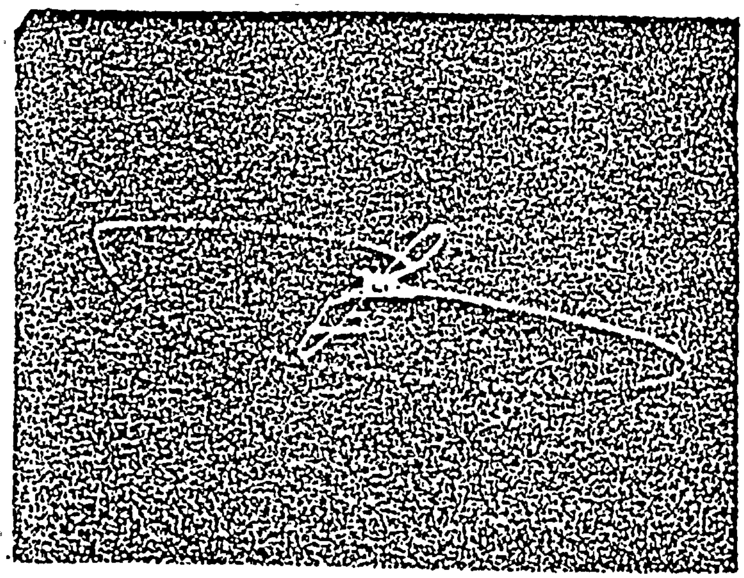


55%

R14C29

2" ATS

11/80



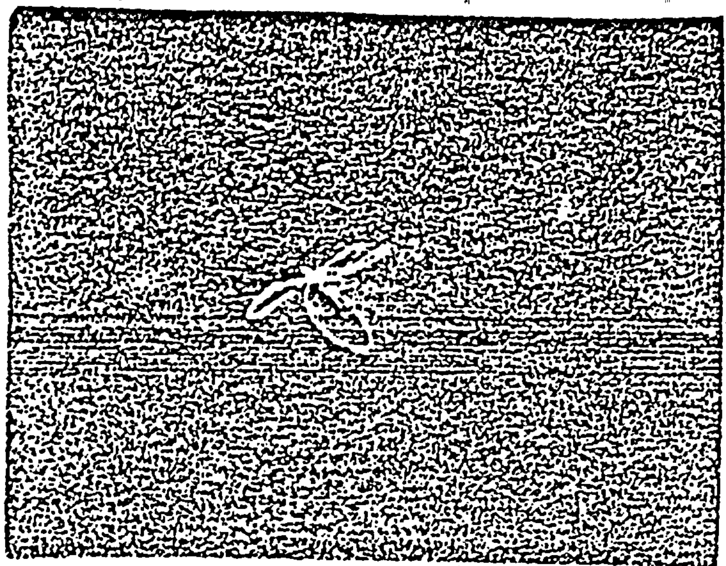
46%

TURKEY POINT #4(FLA)

S/G-B C.L.

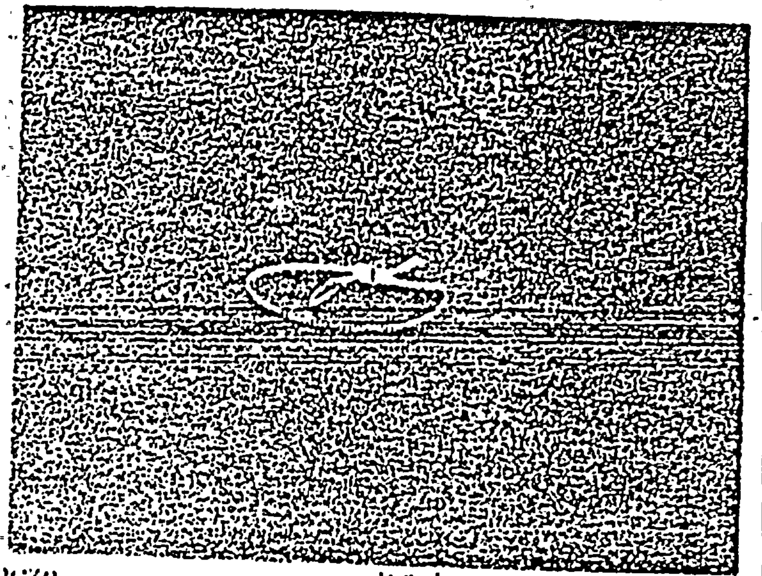
2 Volts/Division

4/79



55°

5/80

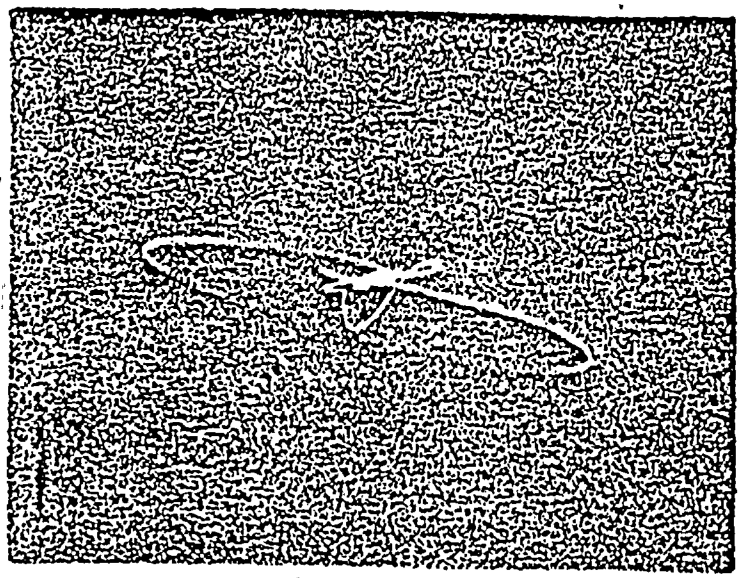


55°

R12C30

2? ATS

11/80



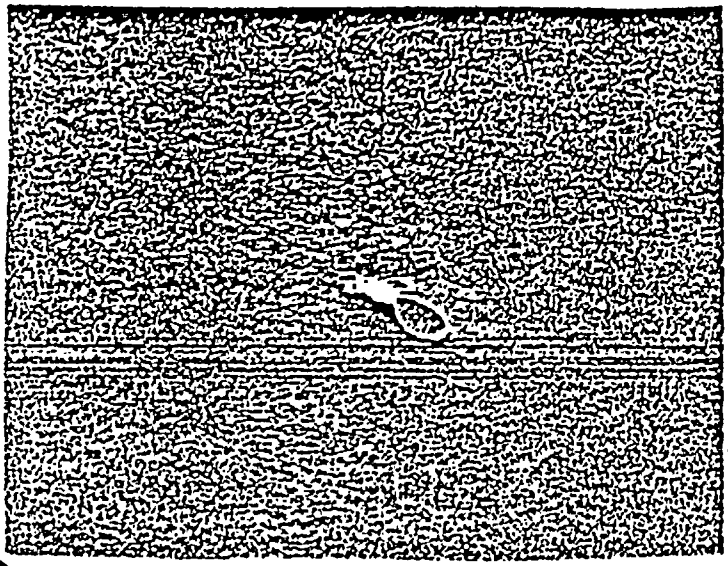
55°

TURKEY POINT #4(14A)

S/G B C.L.

2 Volts/Division

4/79



Not Quantified

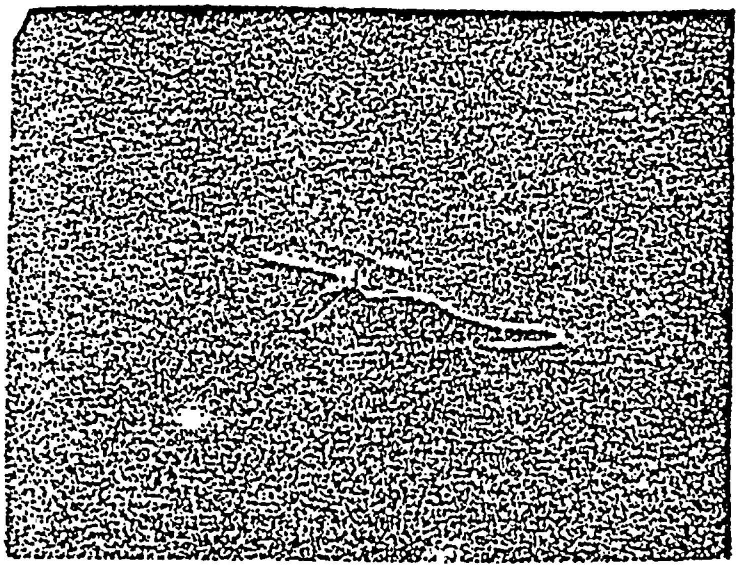
5/80

Not Tested

R23C39

2" ATS

11/80



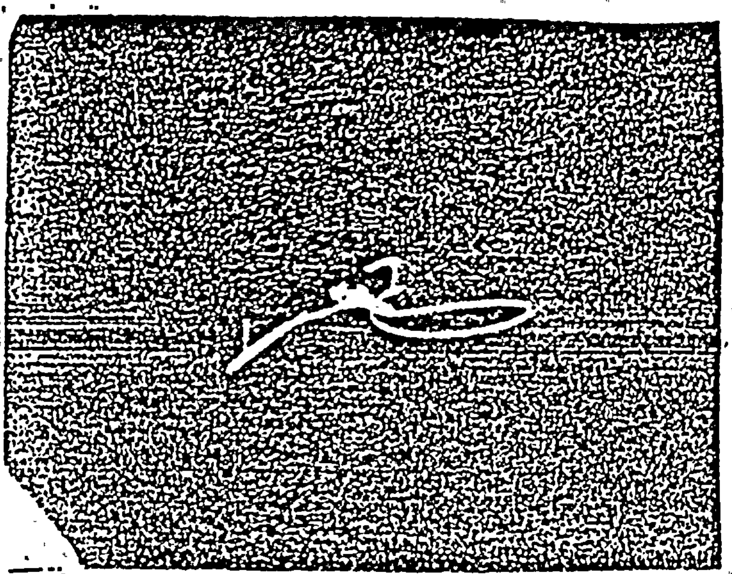
43%

TURKEY POINT #4 (H.

S/G-B C.L.

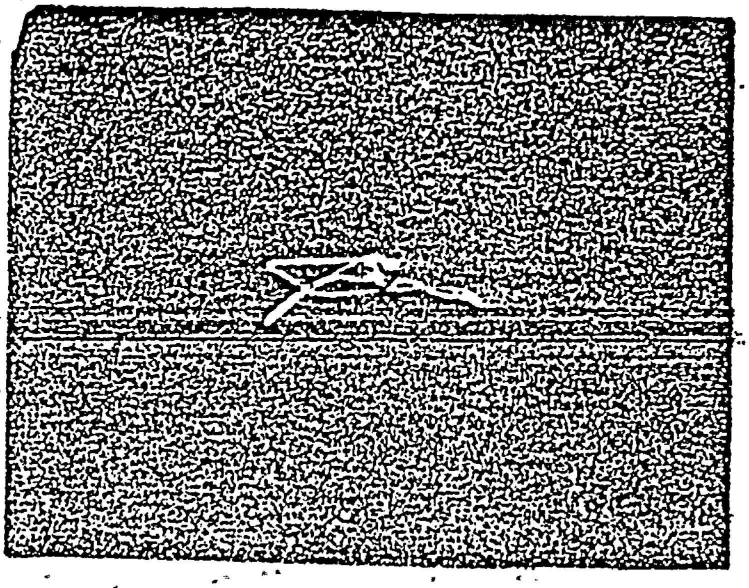
2 Volts/Division

4/79



38%

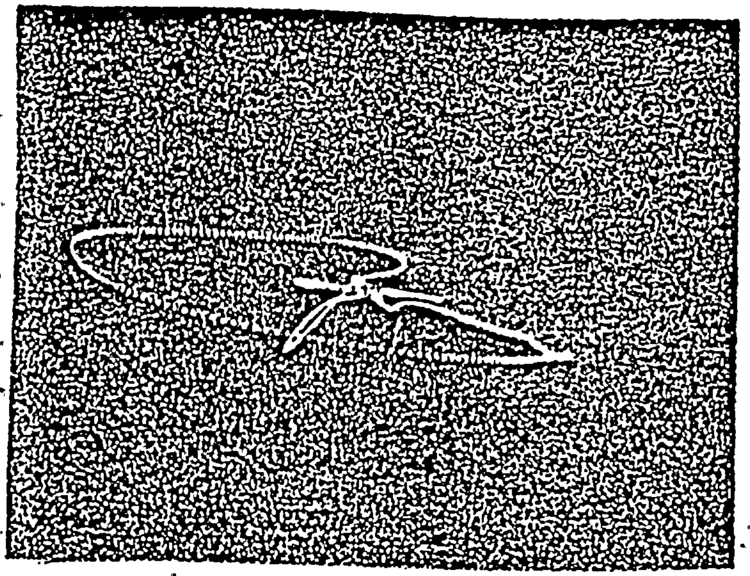
5/80



31 %

R24C39

1" ATS



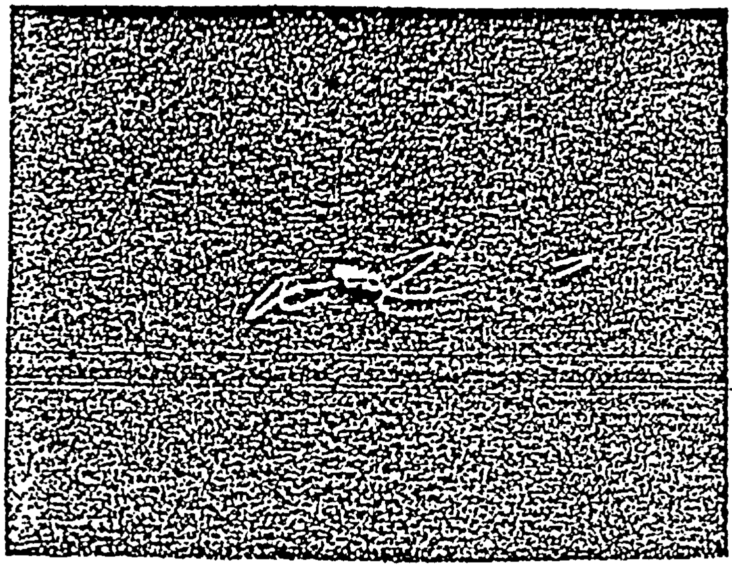
44%

TURKEY POINT #4(FLA)

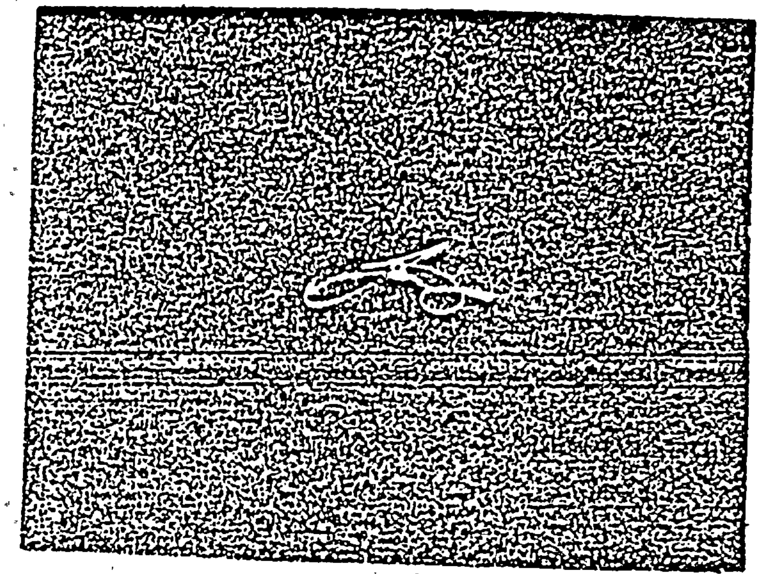
S/G-B C.L.

2 Volts/Division

4/79



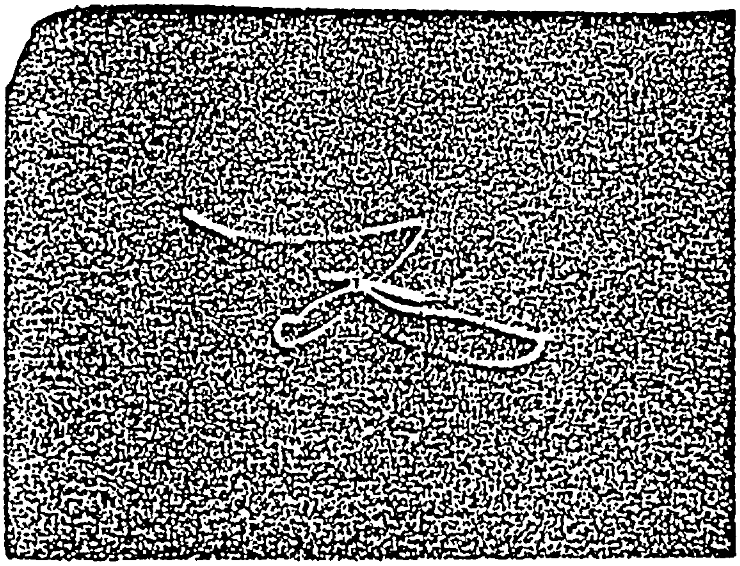
5/80



< 20% R24C40 24%

½" ATS

11/80



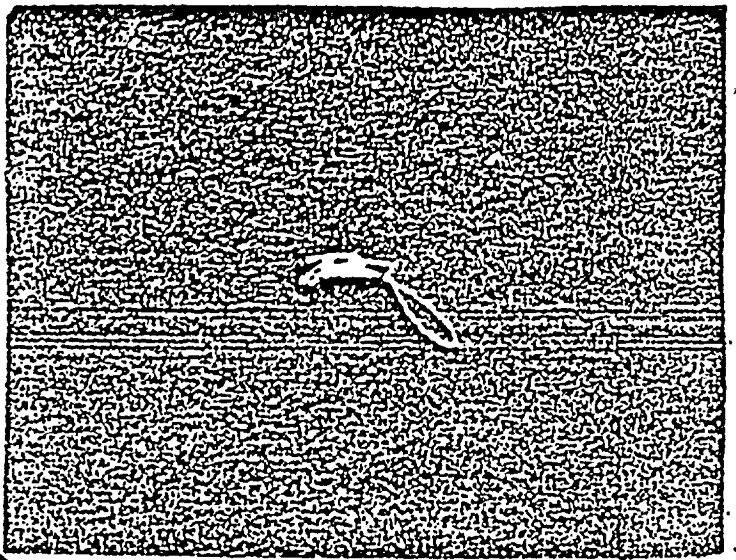
41%

TURKEY POINT #4(FLA)

S/G-B C.L.

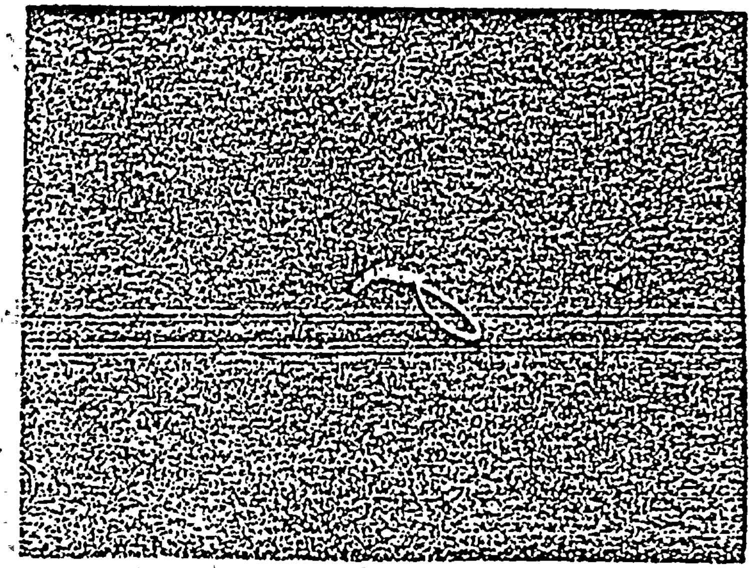
2 Volts/Division

4/79



24%

5/80

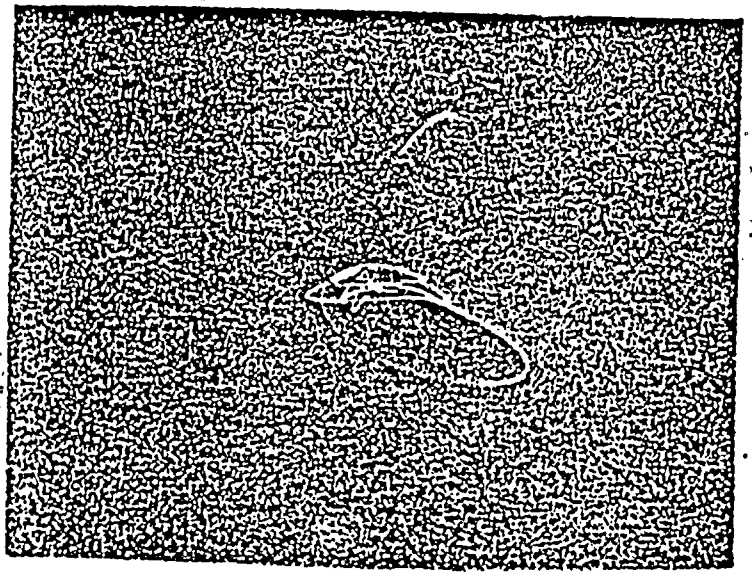


36%

R11C44

2" ATS

11/80



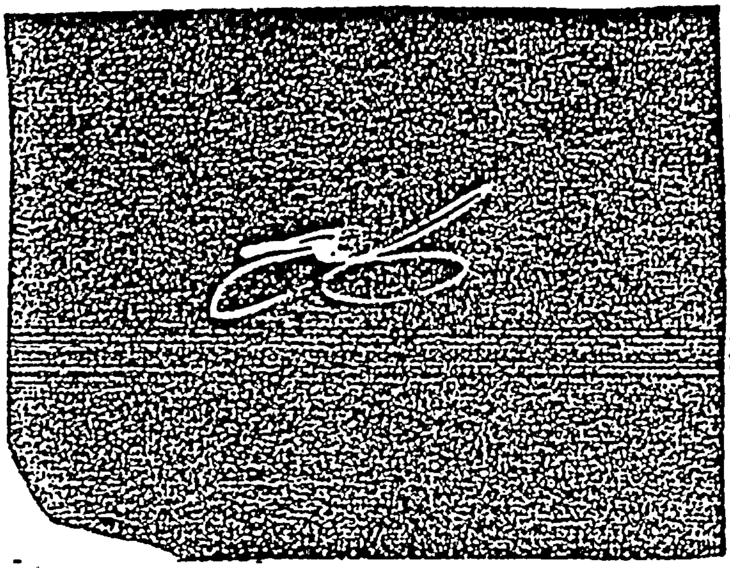
53%

TURKEY POINT #4(FLA)

S/G-B C.L.

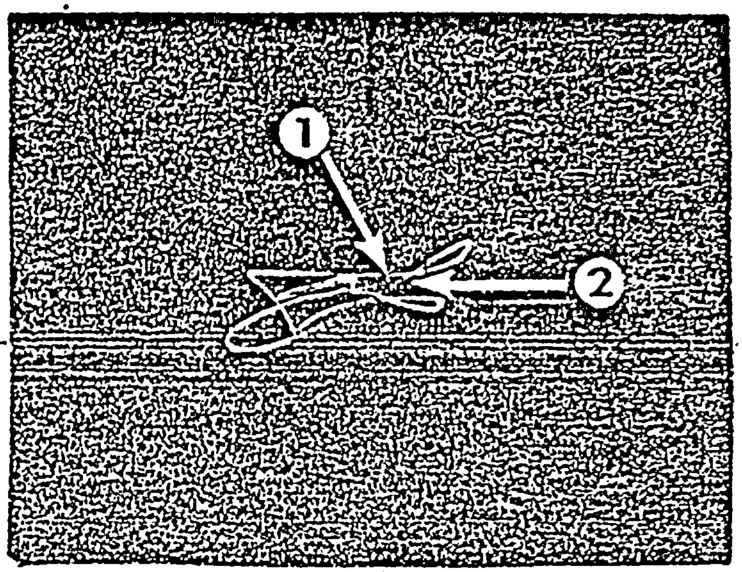
2 Volts/Division

4/79



28%

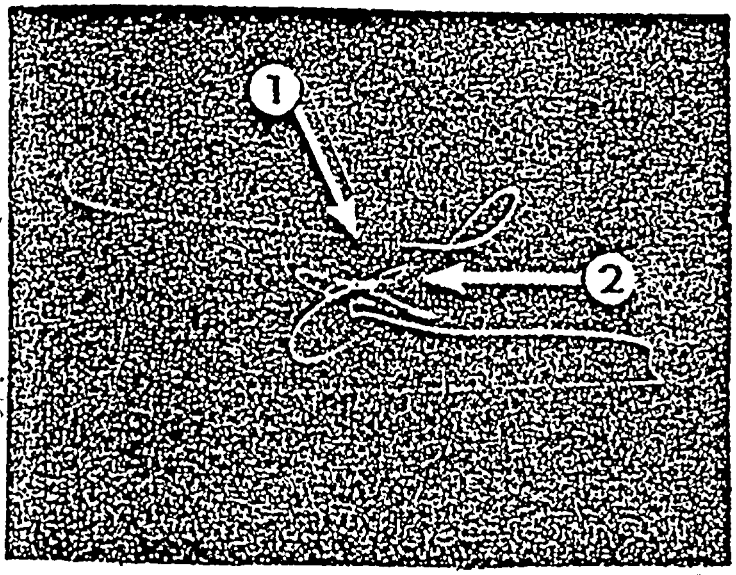
5/80



28%

R22C44
1" ATS

11/80



45%

TURKEY POINT #4(FLA)

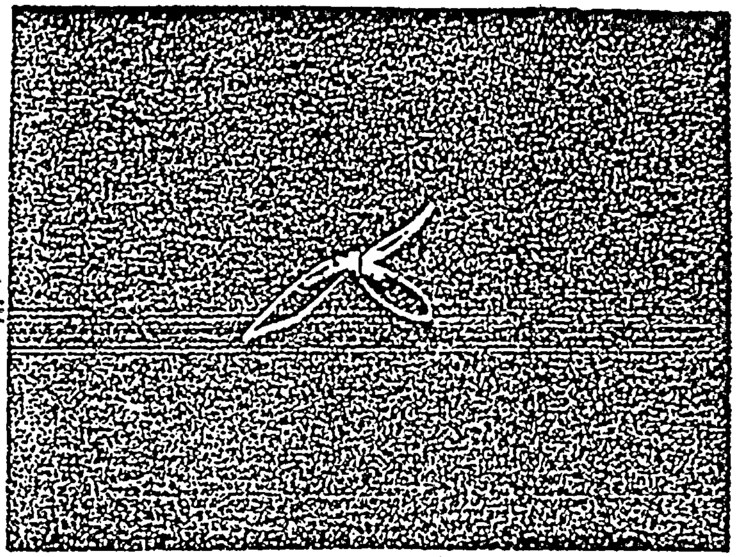
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

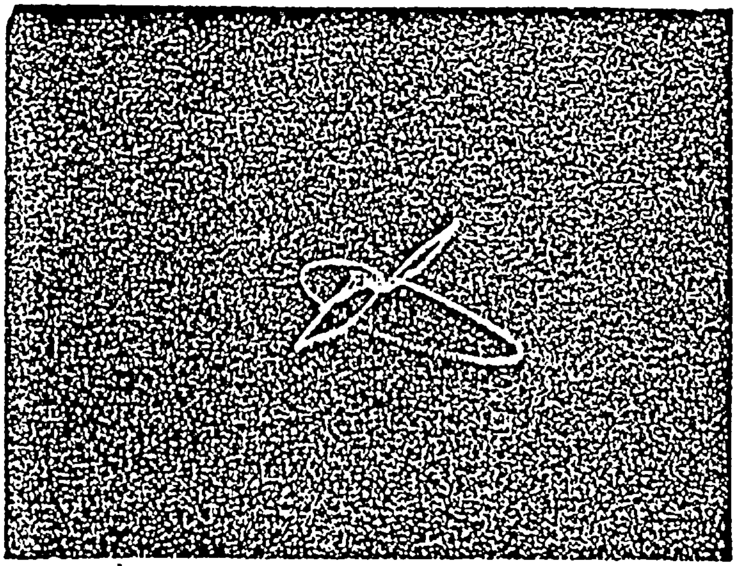
5/80



R10C46
2" ATS

37%

11/80



45%

TURKEY POINT #4(1-LA) FIG. A-22

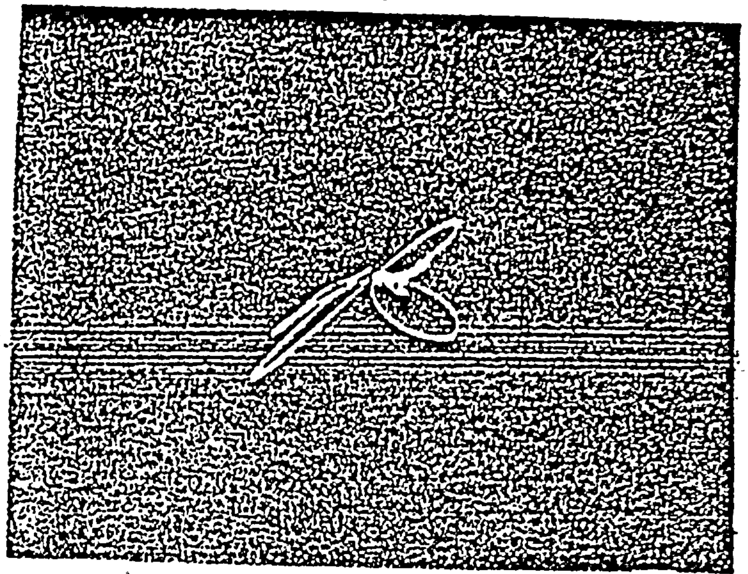
S/G-B C.L.

2 Volts/Division

4/79

Not Tested

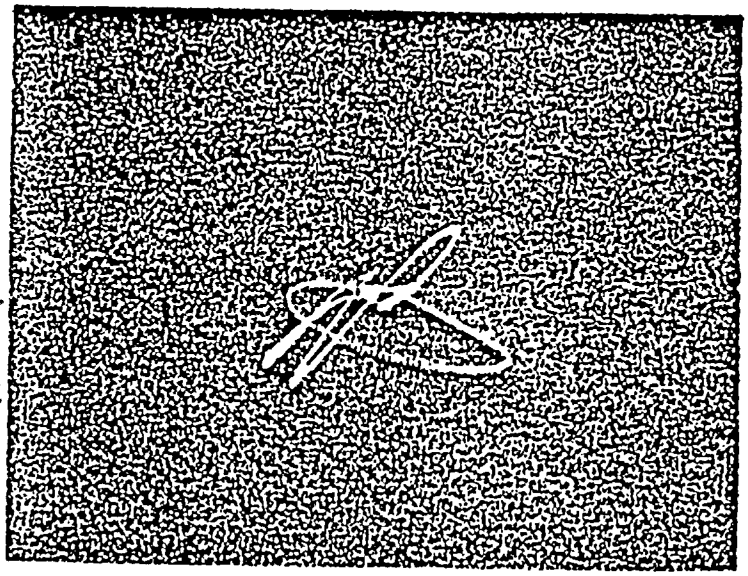
5/80



R11C46 39%

2" ATS

-11/80



45%

TURKEY POINT #4(FLA)

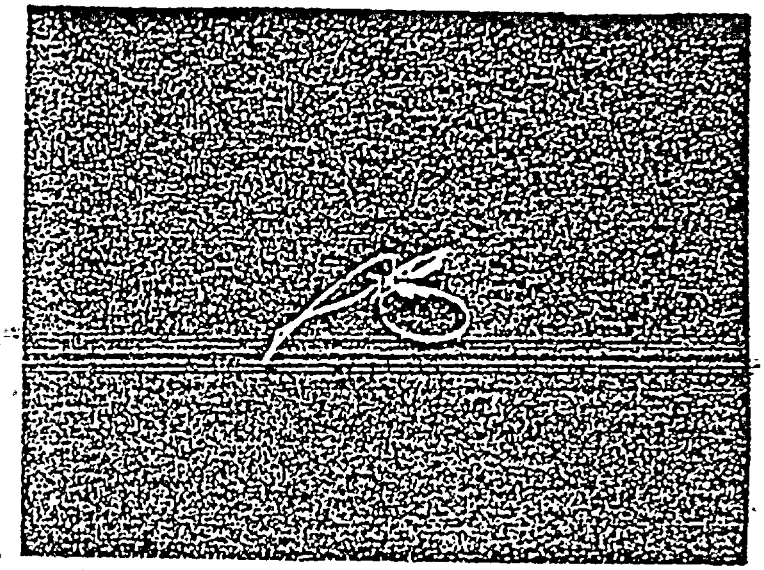
S/G-B C.L.

2 Volts/Division

4/79

5/80

NOT TESTED

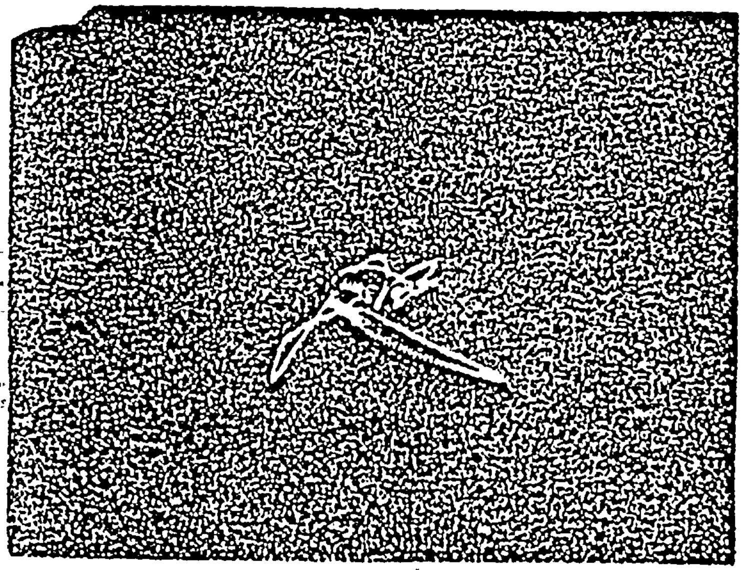


R13C46

3" ATS

33%

11/80



51%

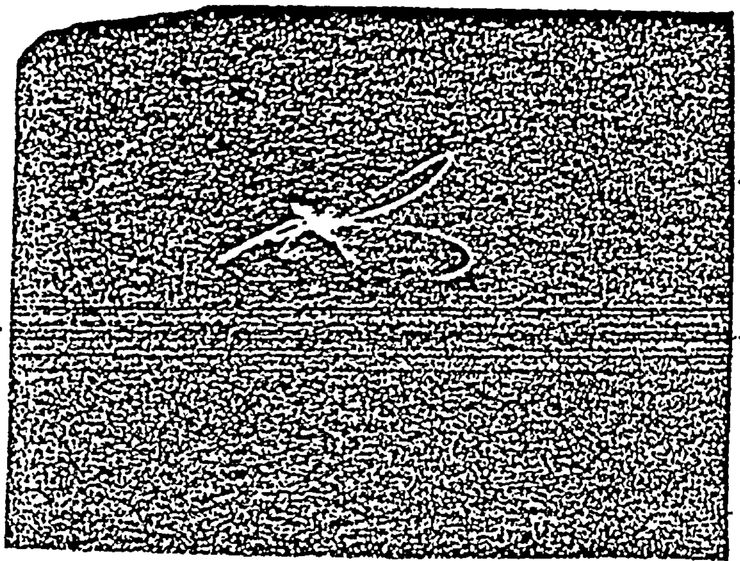
TURKEY POINT #4(FLA)

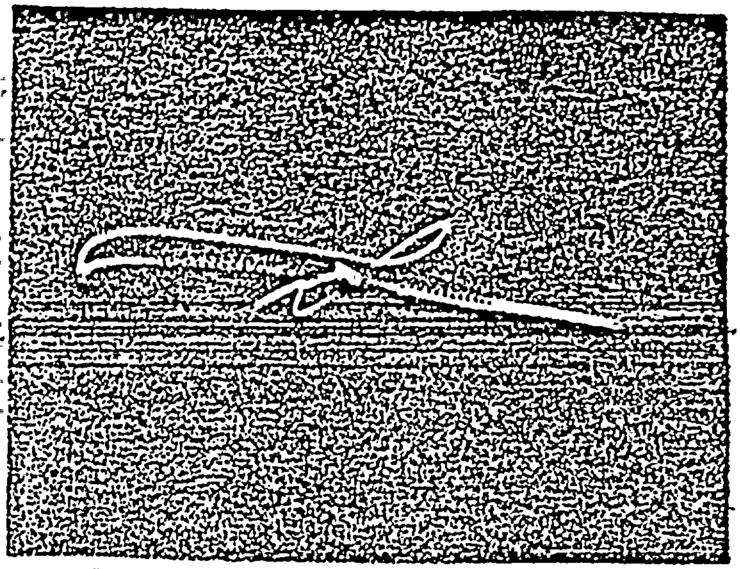
S/G-B C.L.

2 Volts/Division

4/79

5/80





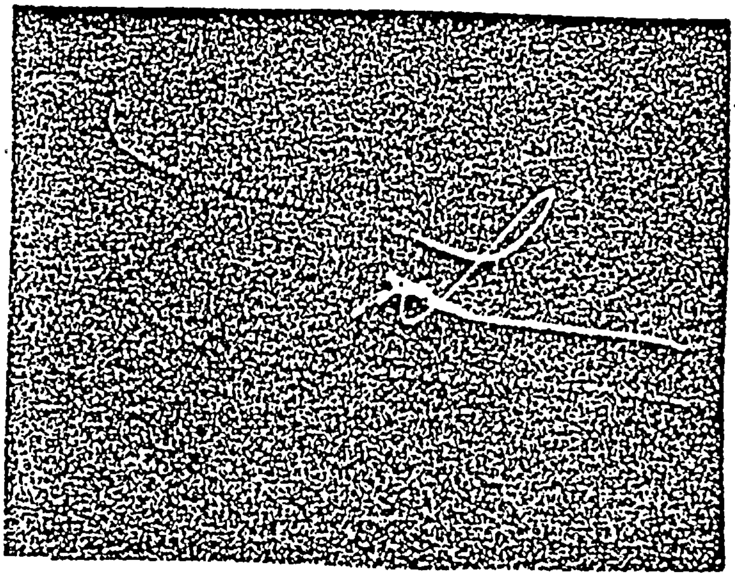
32%

R22C46

32%

½" ATS

11/80



49%

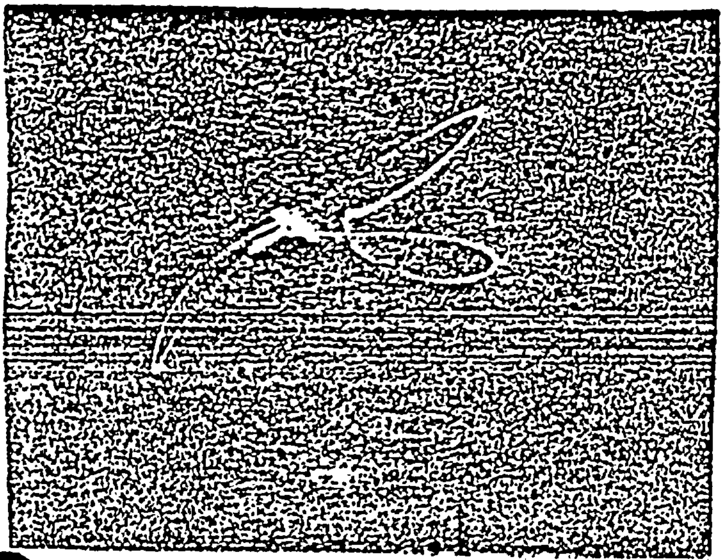
FIG. A-25

TURKEY POINT #4(FLA)

S/G-B C.L.

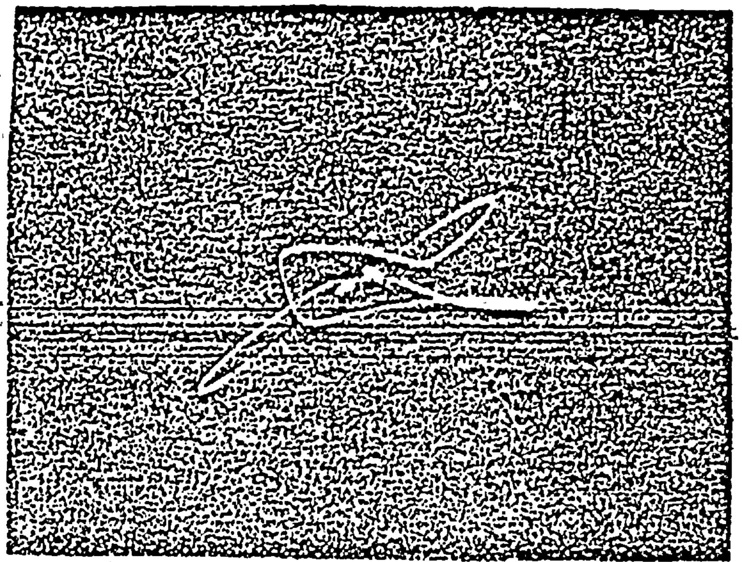
2 Volts/Division

4/79



55%

5/80

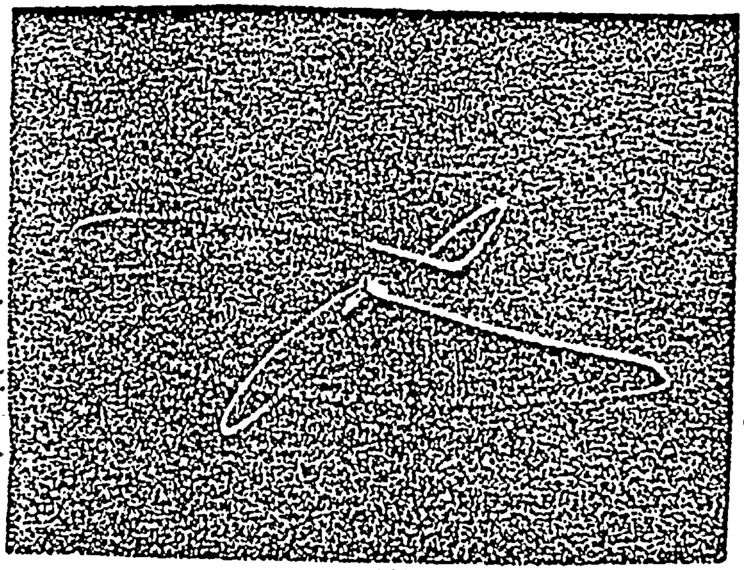


52%

R23C46

1" ATS

11/80

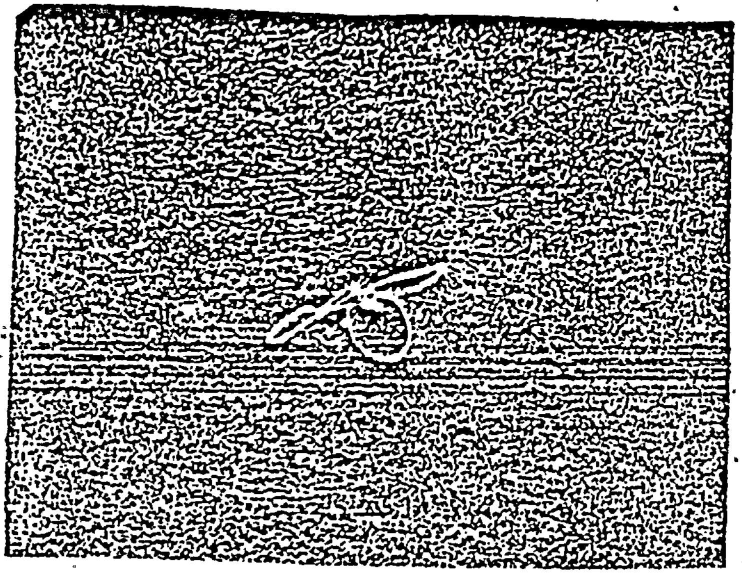


41%

S/G-B C.L.

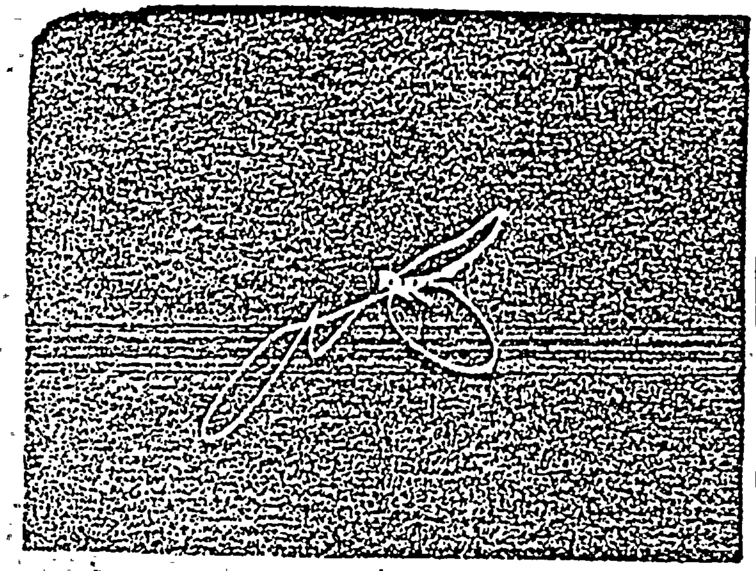
.2 Volts/Division

4/79



22%

5/80

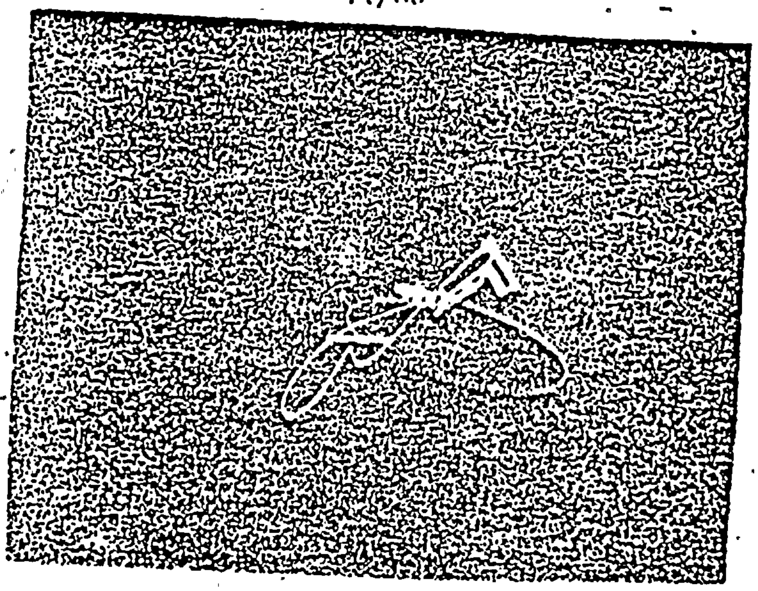


39%

R10C47

3" ATS

11/80



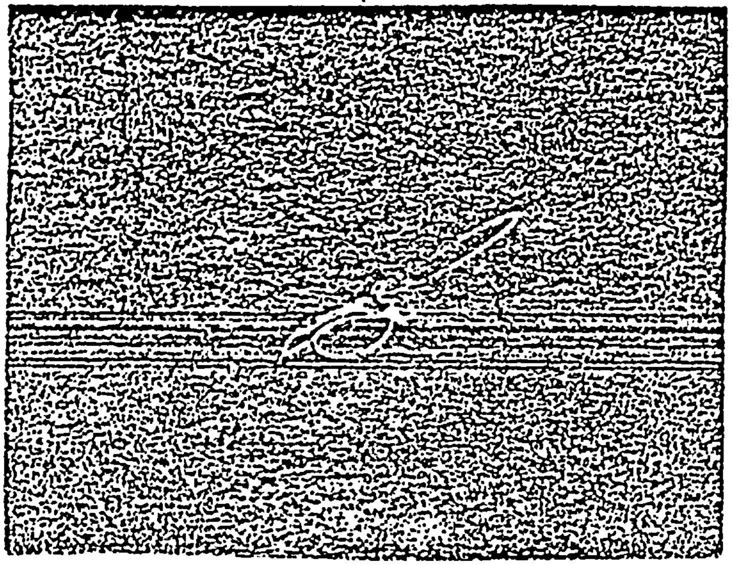
47%

TURKEY POINT #4(FIE...

S/G-B C.L.

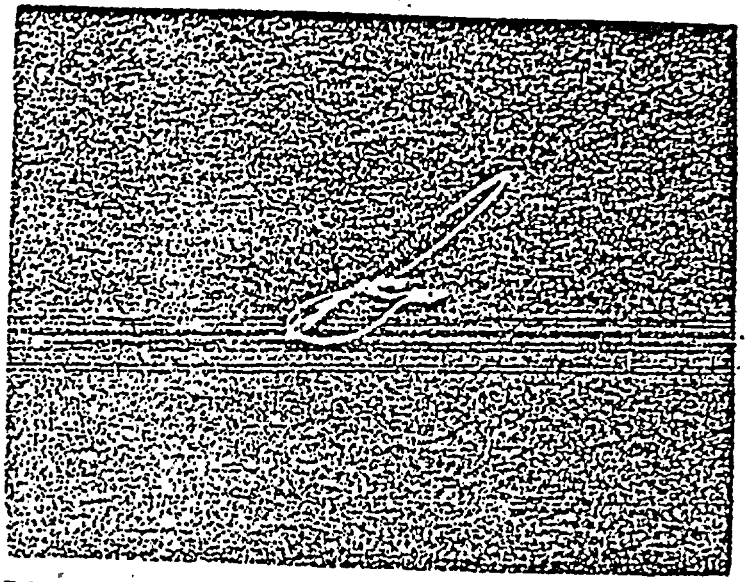
2 Volts/Division

4/79



31%

5/80

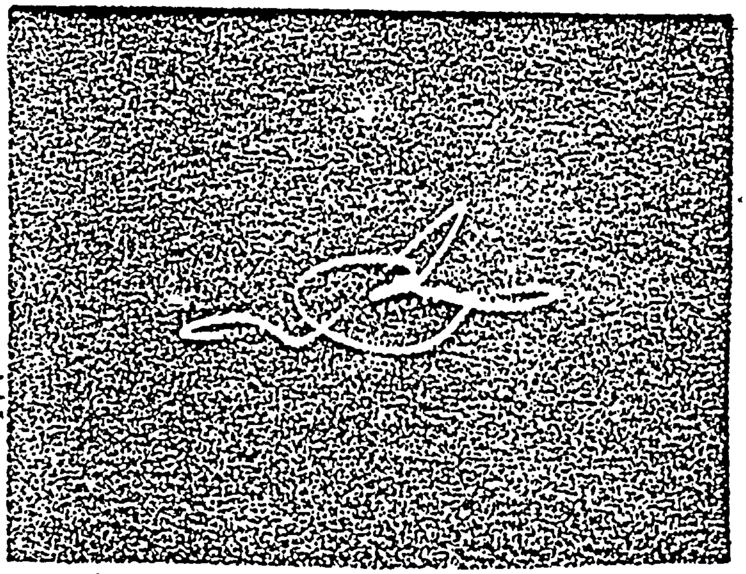


37%

R7C62

2" ATS

11/80

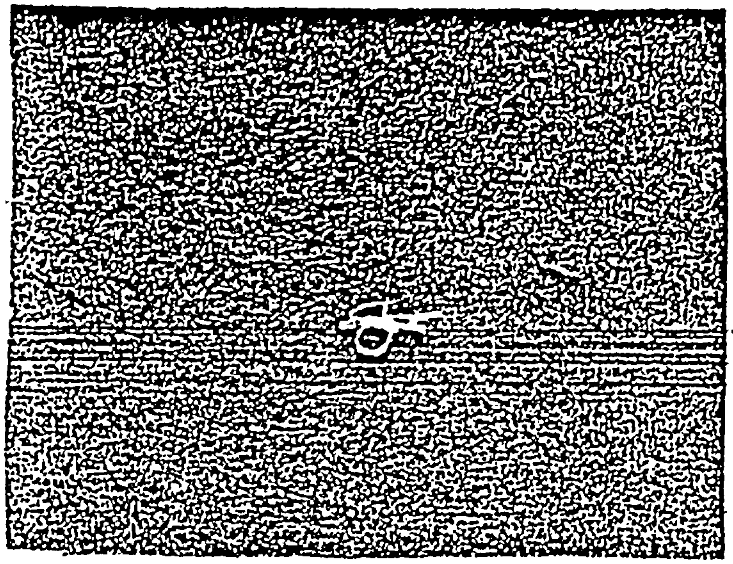


42%

S/G-B C.L.

2 Volts/Division

4/79



5/80

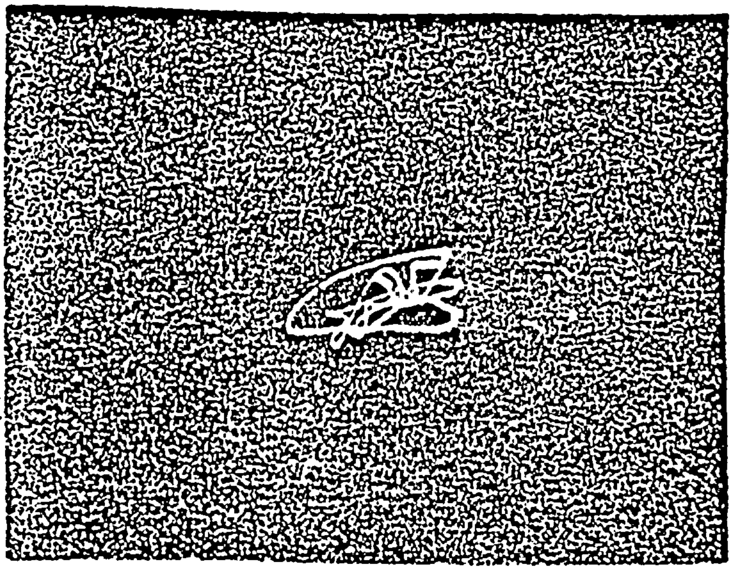
Not Tested

Not Quantified

R7C64

2" ATS

11/80

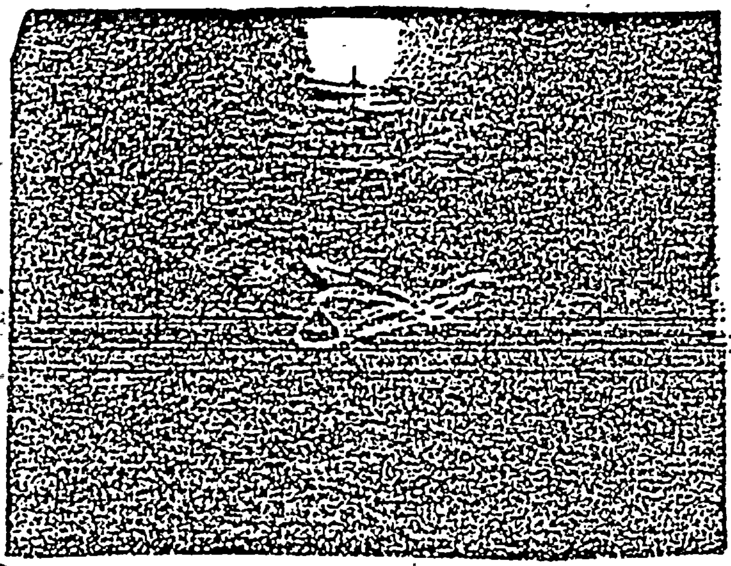


57%

S/G-B C.L.

2 Volts/Division

4/79



Not Quantified

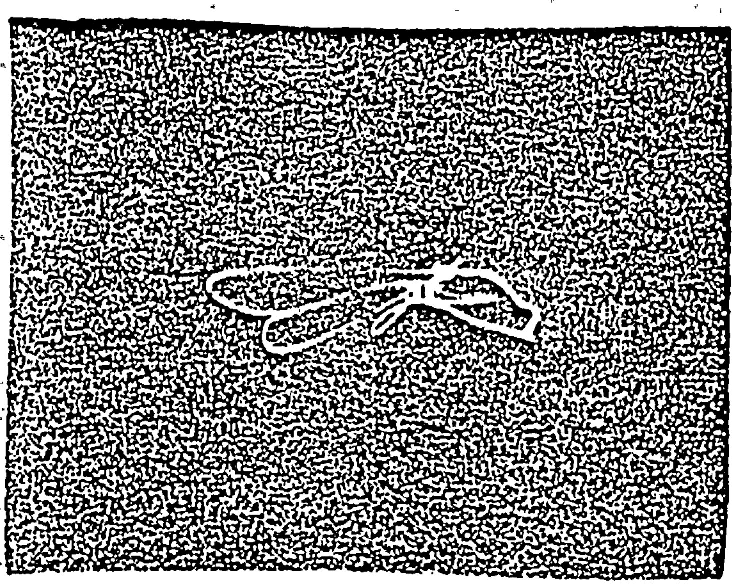
5/80

Not Tested

R7C65

3" ATS

11/80

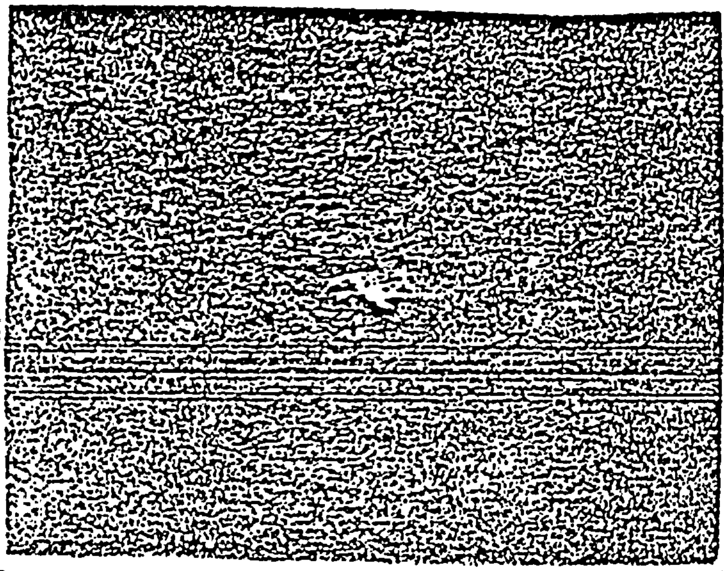


TURKEY POINT #4(FLA)

S/G-B C.L.

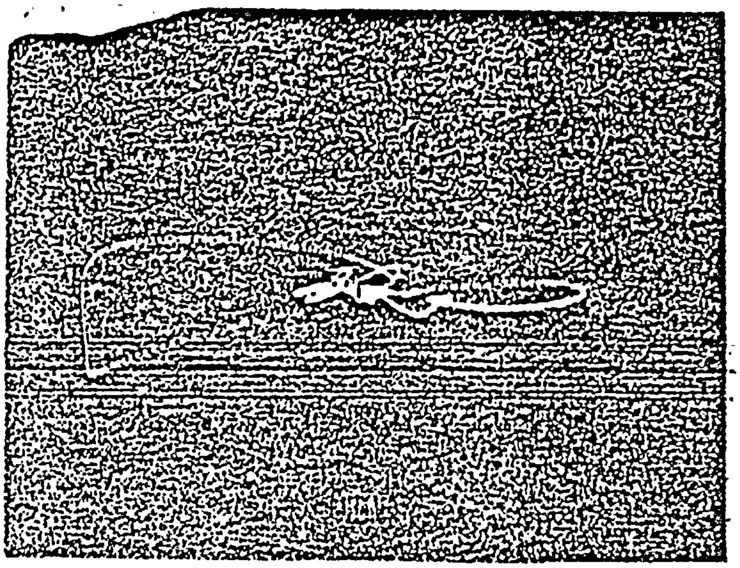
2 Volts/Division

4/79



40%

5/80

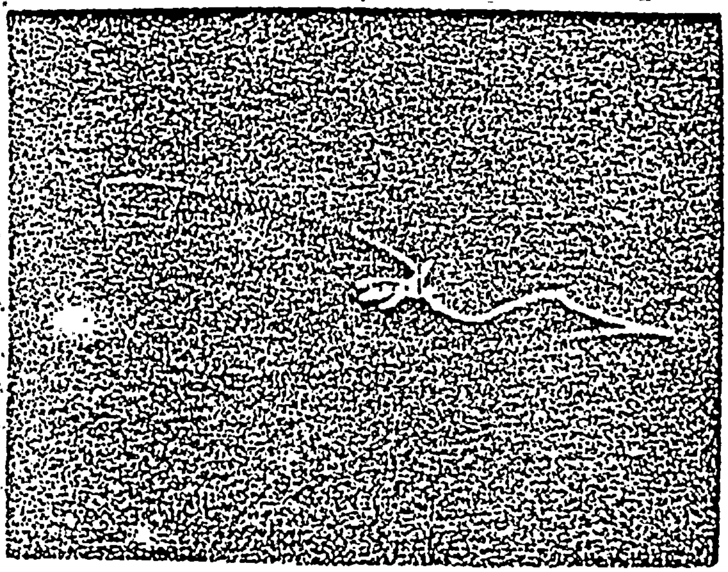


22%

R17C69

3" ATS

11/80

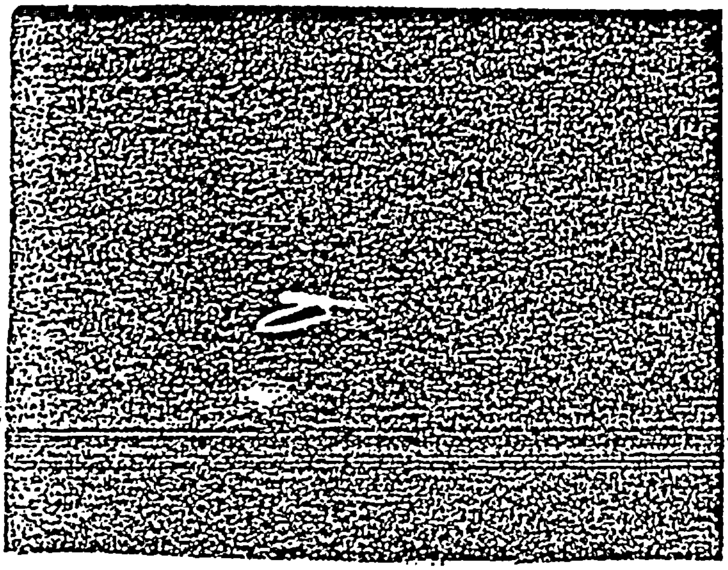
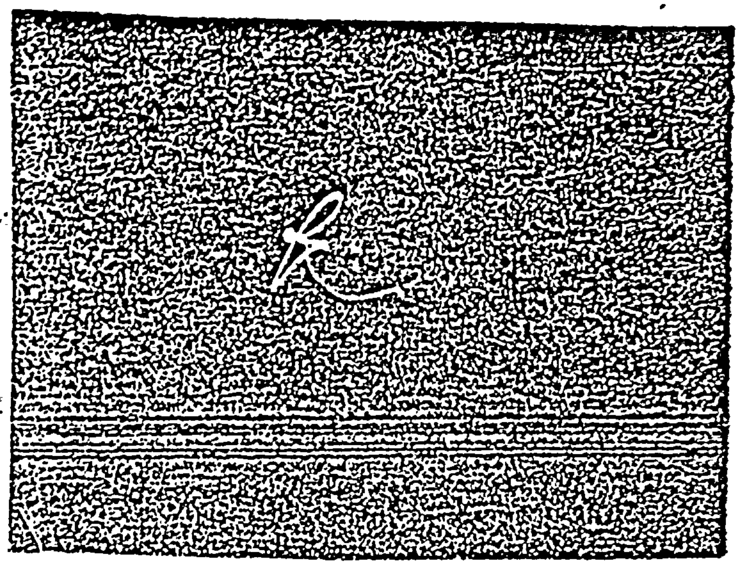


44%

TURKEY POINT #4(FLA)

S/G-C H.L.

2 Volts/Division

4/79		11/80
		
Not Quantified	R44C53 1" ATS	51%

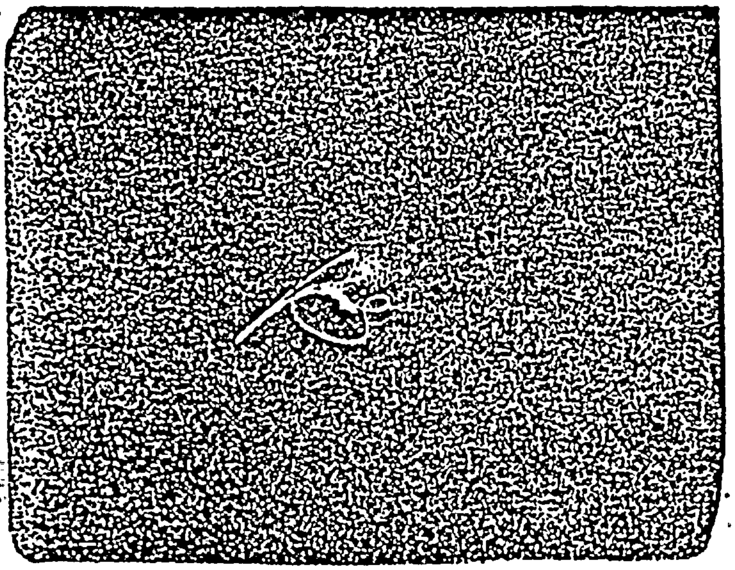
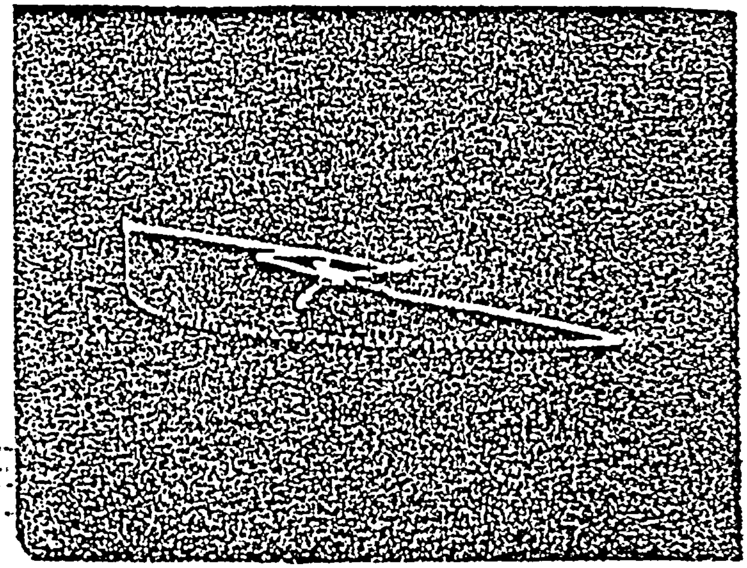
5/75		11/80
		
36%	R14C53 2" ATS	49%

FIG. A-32

TURKEY POINT #4(FLA)

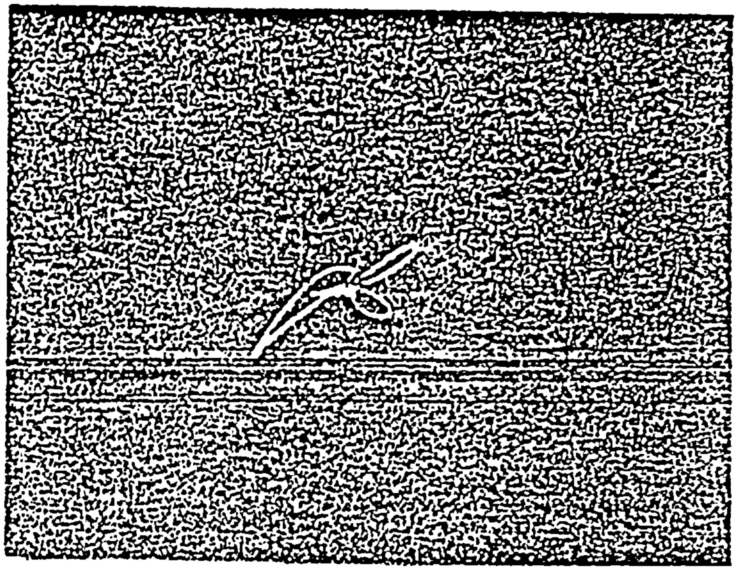
S/G-C C.L.

2 Volts/Division

4/79

51%

5/80

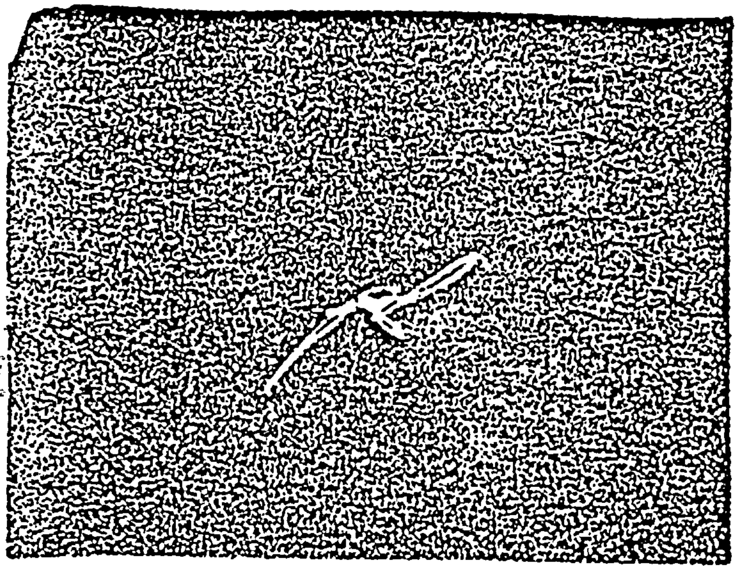


51%

R10C46

2" ATS

11/80



44%

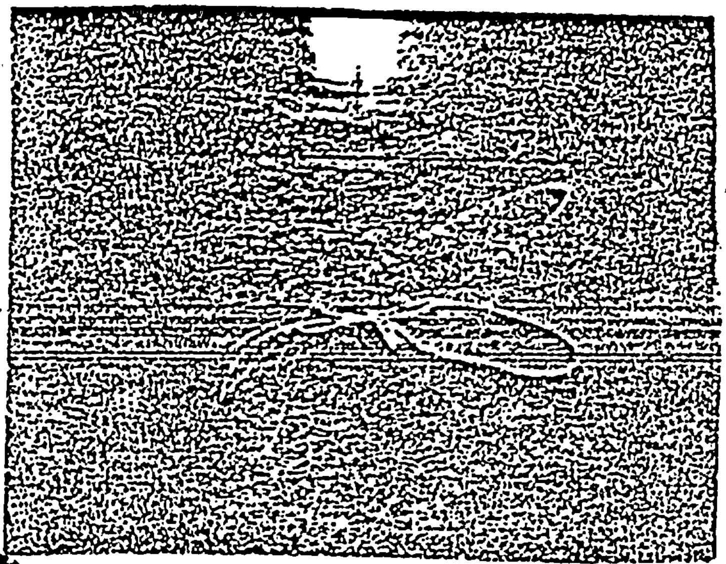
FIG. A-33

TURKEY POINT #4 (FLA)

S/G-C C.L.

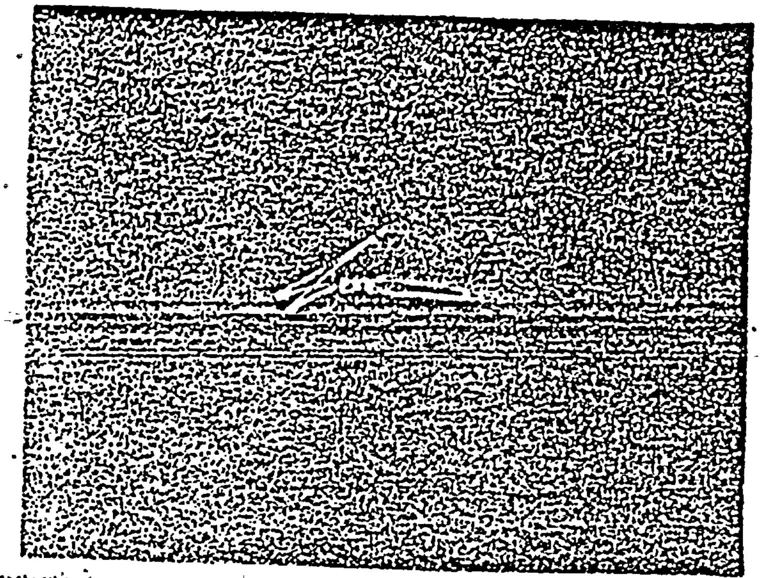
2 Volts/Division

4/79



30%

5/80

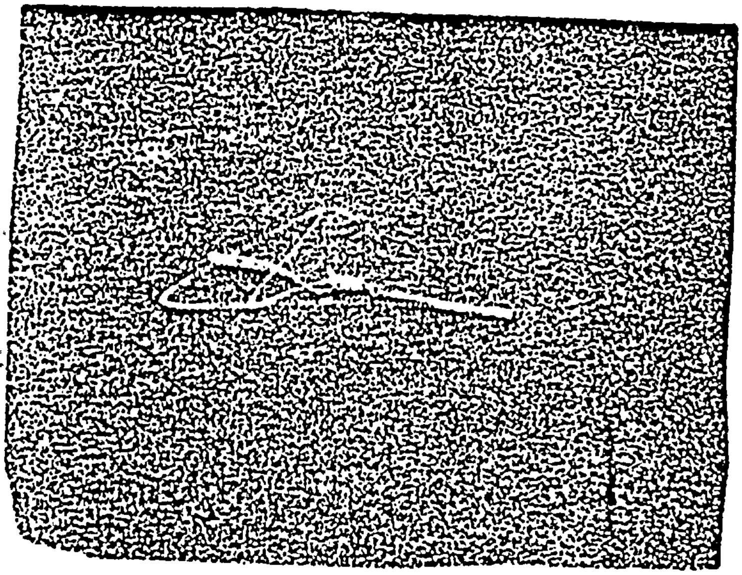


55%

R5C58

TTS

11/80



44%

APPENDIX B

FPL (SERIES 44) SG TUBE INTEGRITY EVALUATION

Minimum Wall thickness Requirement to Safeguard Against Burst and Collapse of Tubing With Localized Degradation at the Top of Tubesheet

On the basis of extensive testing of typical PWR steam generator tubing, it is known that for the straight length tubing the minimum tube wall (t_{min}) requirement to safeguard against burst or rupture during a postulated feed line break (FLB) accident is always more limiting than that for collapse following a postulated LOCA (1)*. Thus, the approach used to establish the minimum required wall thickness for tubing degraded locally at the top of the tubesheet (TTS) consists of (1) computing the t_{min} based on the burst pressure requirement; and (2) verifying that using this t_{min}, the collapse requirement is satisfied for a tube with the maximum expected ovality in the TTS region of the tube bundle. It is to be noted that both the tube burst and collapse strengths used in the following calculations are those associated with the uniform thinning type of defect which is shown to be the most limiting (1). In reality, since thinning tends to be nonuniform, the assumption of minimum ligament being uniform around the entire circumference lends to a somewhat conservative estimate of t_{min}.

Nominal Parameters for the FPL SG Tubing

Outside Diameter, OD = .875 in.
Wall Thickness, t = .050 in.
Inside Diameter, ID = .775 in.
Material, I-600 Mill-annealed
Lower Bound Yield Strength (2),
S_y = 37.8 ksi at Room Temperature
S_y = 30.1 ksi at 600 degrees F
Maximum Ovality in Straight Legs, e_o = 1.5%

* Numbers in brackets designate references at end of Appendix B.

In order to account for the effects of thin wall behavior and the anisotropic yield properties, actual test results, shown in Figure B-2 (1), of uniformly thinned, as manufactured tubing are used. These tests were run at 600 degrees F. The material yield strength was 51.0 ksi at room temperature, and 42.0 ksi at 600 degrees F (based on 12.5% reduction suggested by Figure 79 of Reference 1).

Corresponding to a 74% wall degradation, (t_{min} = .013 inch) the minimum collapse pressure P_c from Figure B-2 is obtained to be 1760 psi (for a defect length of .75 inch). This value is used as the reference collapse pressure of a perfectly round, (this is a conservative assumption) as-manufactured tube thinned uniformly to .013 inch ligament. This value is then adjusted for the actual FPL tubing yield strength of 30,100 psi and ovality of 1.5% using the ANSYS solution discussed above.

For the given ovality and $R_{m/t}$ ratio, the collapse pressure is proportional to the yield strength. Hence, the reference collapse pressure for 74% degraded FPL tubing is:

$$P_C = 1760 \times 30{,}100/42000 = 1260 \text{ psi}$$

From the ANSYS solution in Figure B-1, the ratio of normalized collapse pressure of round tube to a 1.5% oval tube is:

$$\frac{P_o}{P_{1.5}} = \frac{.775}{.97} \simeq .8$$

Hence, the minimum predicted collapse pressure of 74% degraded FPL tubing in the straight leg regions is:

$$P_{1.5} = .8 \times 1260 = 1000 \text{ psi.}$$

Note that if the defects are in the proximity of the tubesheet, the actual resistance to collapse would be increased somewhat due to the end constraint.

Burst Strength Requirements

The maximum primary-to-secondary pressure of 2560 (2) psi across the tube wall occurs during a postulated FLB accident. To safeguard against tube rupture under this loading at 600 degrees F, t_{min} = .013 (2) inch has been established for a nominal .775 inch ID, I-600 MA tubing. That analysis used a conservative lower bound of 10,000 psi room temperature burst pressure for a nominal .875 x .050 wall tubing.

Verification for Collapse Requirement

A number of studies on the external pressure collapse response of typical SG tubing have been reported (1, 3). Even though the tube ovality is known to reduce significantly the resistance to collapse, accurate analytical formulation is difficult to derive because of material anisotropy and increasing ovality under pressure loading (that is, Lagrangian formulation). Additionally, in the case of degraded tubes with a remaining wall on the order of 25% of nominal, the effect of failure mode being elastic buckling rather than plastic collapse should also be considered.

For the lack of a comprehensive, unified theory encompassing the effects of all the above variables, the following conservative approach is needed for verification of t_{min} against collapse.

From the results in Reference (3), it is observed that the limit analysis theory correlates well with the test results of stress-relieved tubing which is believed to have less anisotropic yield properties than as-manufactured tubing. The theoretical prediction is rather excellent for speciments with small initial ovalities. Nevertheless, in order to account for continued increase in ovality under the external pressure loading, a large-deformation finite element solution (ANSYS STIF48) using elastic-perfectly plastic shell behavior is utilized for the actual verification. The finite element solution along with the limit analysis theory and actual test results is shown in Figure B-1.

For the FPL SG units, the maximum secondary to primary pressure due to LOCA is 770 psi (4). The required minimum collapse pressure in accordance with the Section III criterion is 860 psi (770/.9). Since the predicted strength is in excess of the required minimum, t_{min} = .013 inch is verified against failure due to collapse.

References

1. Vagins, M., et al., "Steam Generator Tube Integrity Program - Phase I Report", NUREG/CR-0718, September, 1979.

2. Smith, P.G., and Sun, C.L., "CPL Steam Generator Tube Plugging Criteria Calculations", WTD-SM-77-058, Revision 1, July, 1977.

3. Small, N.C., "Plastic Collapse of Oval Straight Tubes Under External Pressure," ASME Paper 77-PVP-57, June, 1977.

4. Turkey Point Units 3 & 4 LOCA Analyses.

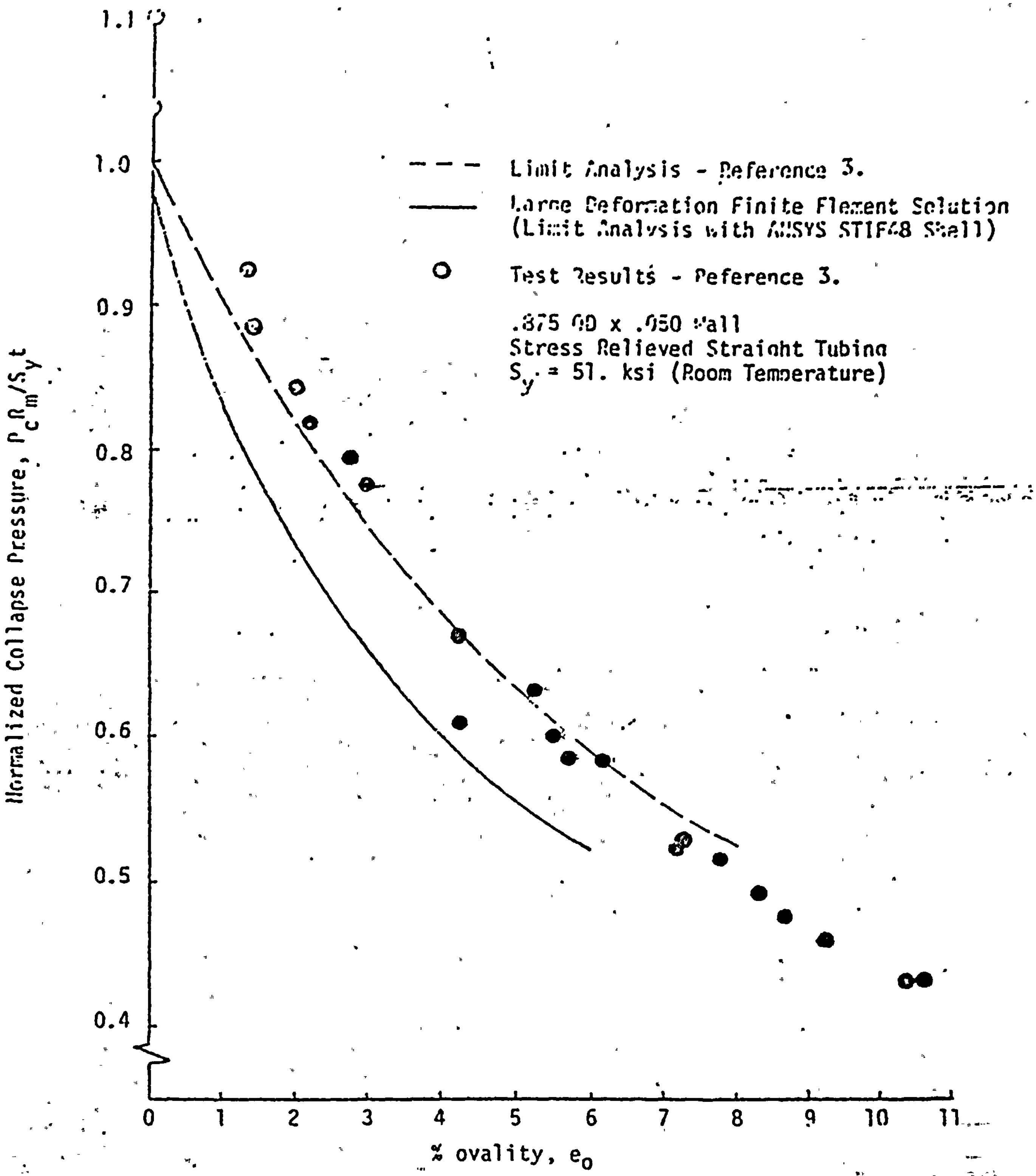


FIGURE B-1 COLLAPSE PRESSURE OF STRAIGHT OVALIZED TUBES - CORRELATION BETWEEN TEST AND ANALYSES

[illegible] [illegible]

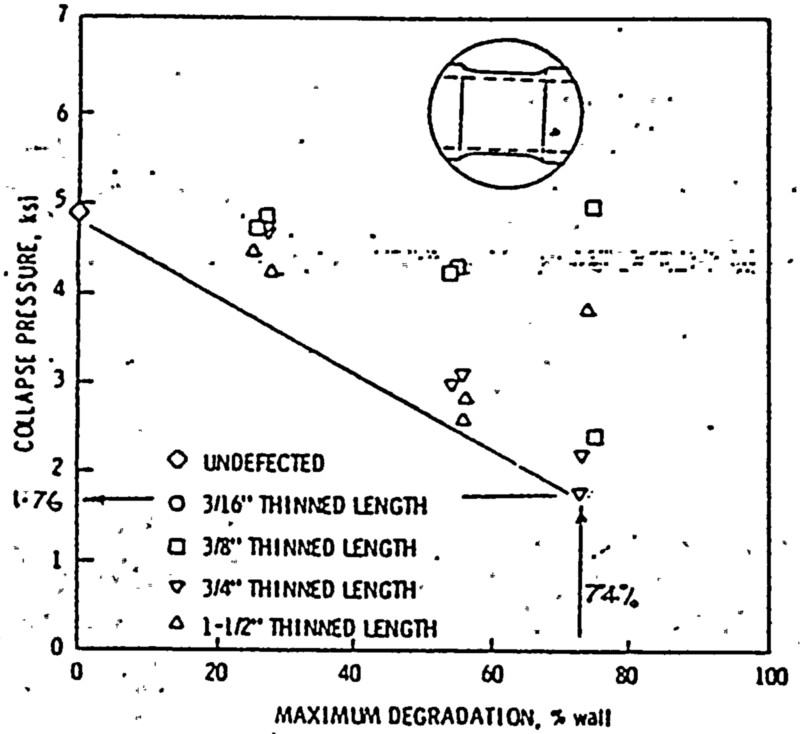


FIGURE B-2 Collapse Pressure Data for 0.875 x 0.050 Uniform Thinning Specimens - Ref. [1]

ATTACHMENT - FPL SYSTEM LOAD CONDITIONS JULY - OCTOBER, 1981

FORECASTED PEAK LOADS (MW)

* JULY	AUG.	SEPT.	OCT.
9610	9630	9630	8620

NOTE (1) These forecasted peaks could very probably be low, as last year's actual July peak load was 9632 MW.

NOTE (2) The southeast Florida loads are 70% of the above system loads.

NOTE (3) The generation transfer limit into southeast Florida during this summer (assuming the worst case transmission line out of service) is 1150 MW at the 9630 NW load level.

FPL'S TOTAL INSTALLED CONTINUOUS SUMMER CAPABILITY FOR SOUTHEAST FLORIDA 7743 MW [6438 MW STEAM + 1305 MW DIESEL & GAS TURBINES].

NOW ASSUMING BOTH TURKEY POINT UNITS ARE OUT OF SERVICE (646 MW PER UNIT).

7743 - 1292 = 6451 MW AVAILABLE

SINCE IMPORT LIMIT IS 1150 MW:

6451 + 1150 = 7601 MW TOTAL AVAILABLE TO SOUTHEAST FLORIDA

SOUTHEAST FLORIDA FORECASTED PEAK LOAD FOR THIS SUMMER IS:

9630 MW X .7 = 6741 MW

RESERVES FOR SOUTHEAST FLORIDA ARE:

7601 MW - 6741 MW = 860 MW

$$\frac{860\ \text{MW}}{6741\ \text{MW}} = 12.8\%\ \text{RESERVE}$$

THIS RESERVE IS CONSIDERABLY BELOW THE RECOMMENDED 20%. NOTE ALSO THAT THIS CALCULATION ASSUMES NO OTHER UNITS OUT OF SERVICE, HENCE ANY OTHER UNIT PROBLEM WOULD MAKE THE CONDITION MORE SEVERE.

*SINCE THIS FORECAST WAS PREPARED & SUBMITTED, WE HAVE HAD AN ACTUAL JULY PEAK OF 9738 MW, THUS INDICATING THAT ACTUAL SYSTEM CONDITIONS MAY BE EVEN MORE SEVERE THAN FORECASTED.