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Westinghouse Energy Systems

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WCAP-12804

STEAM GENERATOR TUBE PLUGGING LIMITS
PRESENTATION MATERIALS

December 1990

G. W. Whiteman

WESTINGHOUSE ELECTRIC CORPORATION
Energy Systems
P. O. Box 355
Pittsburgh, Pennsylvania 15230

WESTINGHOUSE PROPRIETARY CLASS 3

A meeting was held on November 6, 1990, between Alabama Power Company, Westinghouse, and the NRR to discuss alternate steam generator tube plugging criteria for the Farley Unit 2 steam generators.

The following topics were discussed by Westinghouse:

1. Overview of the Farley Unit 2 Assessment

2. Farley 2- Specific Tube Plugging Criteria for Expansion Zone Primary Water Stress Corrosion Cracking in the Roll Transitions

3. Steam Line Break Leakage Limits for Farley Unit 2

4. Farley Unit 2 Eddy Current Inspection Summary

5. Farley Unit 2 Tube Support Plate Criteria

ODSCC at TSPs
Farley-2 Plan

Tube plugging for Farley-2 1990 outage

- o Plug tubes exceeding 1.75 Volt amplitude
- o Basis
  - Previously applied for DIs in 4 Farley - 1, 2 outages
- o No leakage attributable to indications at TSPs
  - Supported by pulled tube, field leakage experience and laboratory testing as a conservative, no leakage tube plugging level
  - Small growth rate for indications at TSPs

Supporting Data

- o Current EPRI program to develop plugging criteria for OD TSPs

ODSCC AT TSPs

EPRI ALTERNATE TUBE PLUGGING CRITERIA

- DEMONSTRATE EITHER OR BOTH OF:
  - TSP CONSTRAINT TO PREVENT TUBE RUPTURE IS PRESENT AT SLB CONDITIONS
  - PLUGGING LIMITS PROVIDE ADEQUATE MARGIN AGAINST TUBE RUPTURE EVEN IF TSP CONSTRAINT IS NOT PRESENT

- TWO PARAMETER PLUGGING CRITERIA
  - BOBBIN COIL VOLTAGE AND DEPTH INDEX LIMITS MUST BOTH BE EXCEEDED FOR TUBE PLUGGING
  - VOLTAGE APPLIED AS A CRACK SEVERITY INDEX BASED UPON VOLTAGE DEPENDENCE ON CRACK LENGTH, DEPTH AND LIGAMENTS (VOLUMETRIC FACTORS)
  - VOLTAGE, DEPTH INDEX LIMITS ESTABLISHED BASED ON CORRELATION WITH POTENTIAL FOR TUBE LEAKAGE
    - LABORATORY INDUCED CRACK SPECIMENS, PULLED TUBE DATA AND FIELD LEAKAGE EXPERIENCE USED TO ESTABLISH LIMITS

- PLUGGING LIMIT
  - TUBE PLUGGING IF: $V > V_L - V_{NDE} - V_{CG}$
    AND $D > D_L - D_{NDE} - D_{CG}$

APC for ODSCC at TSPs
Voltage / Depth Indices

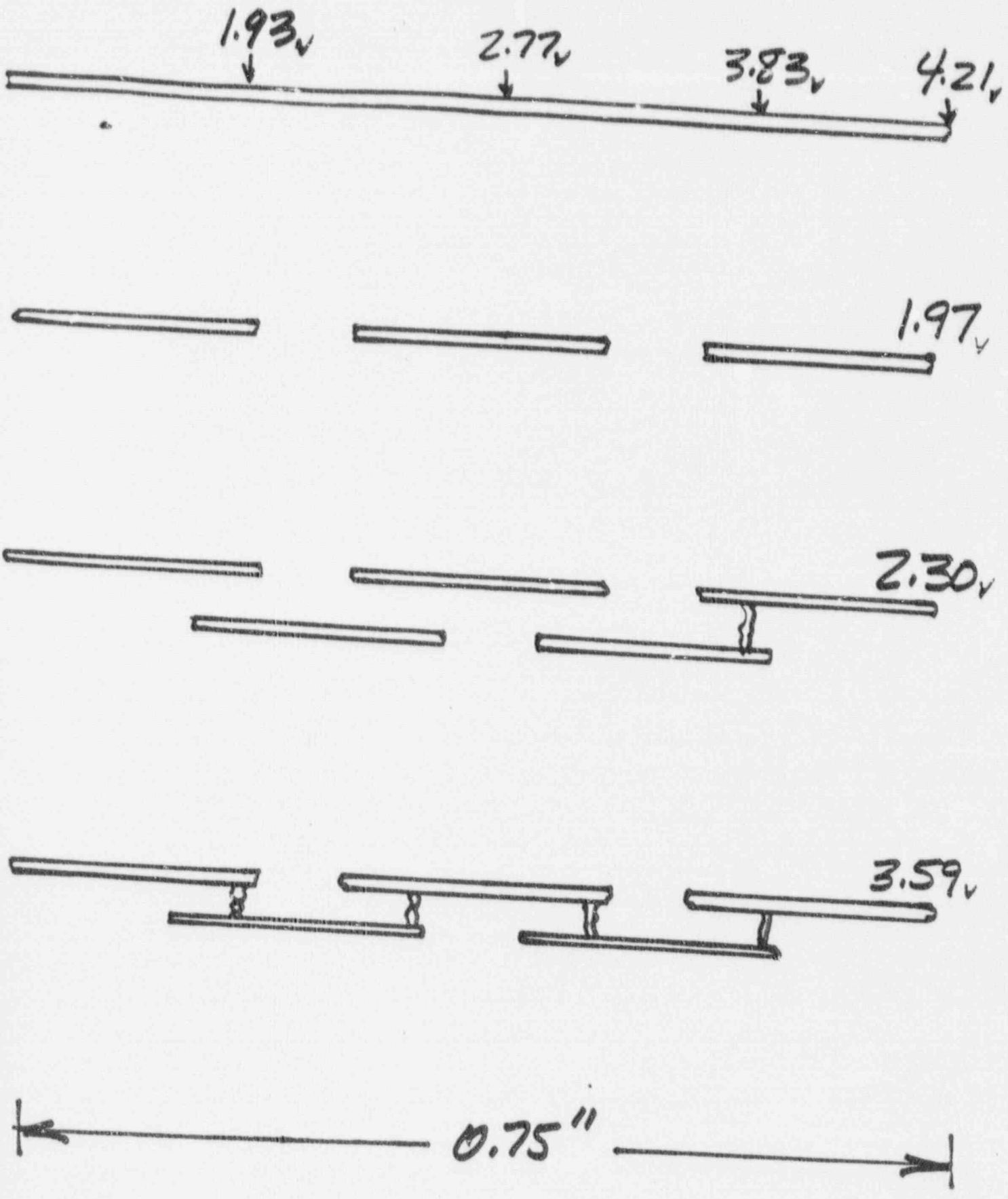
Voltage - Crack Severity Index

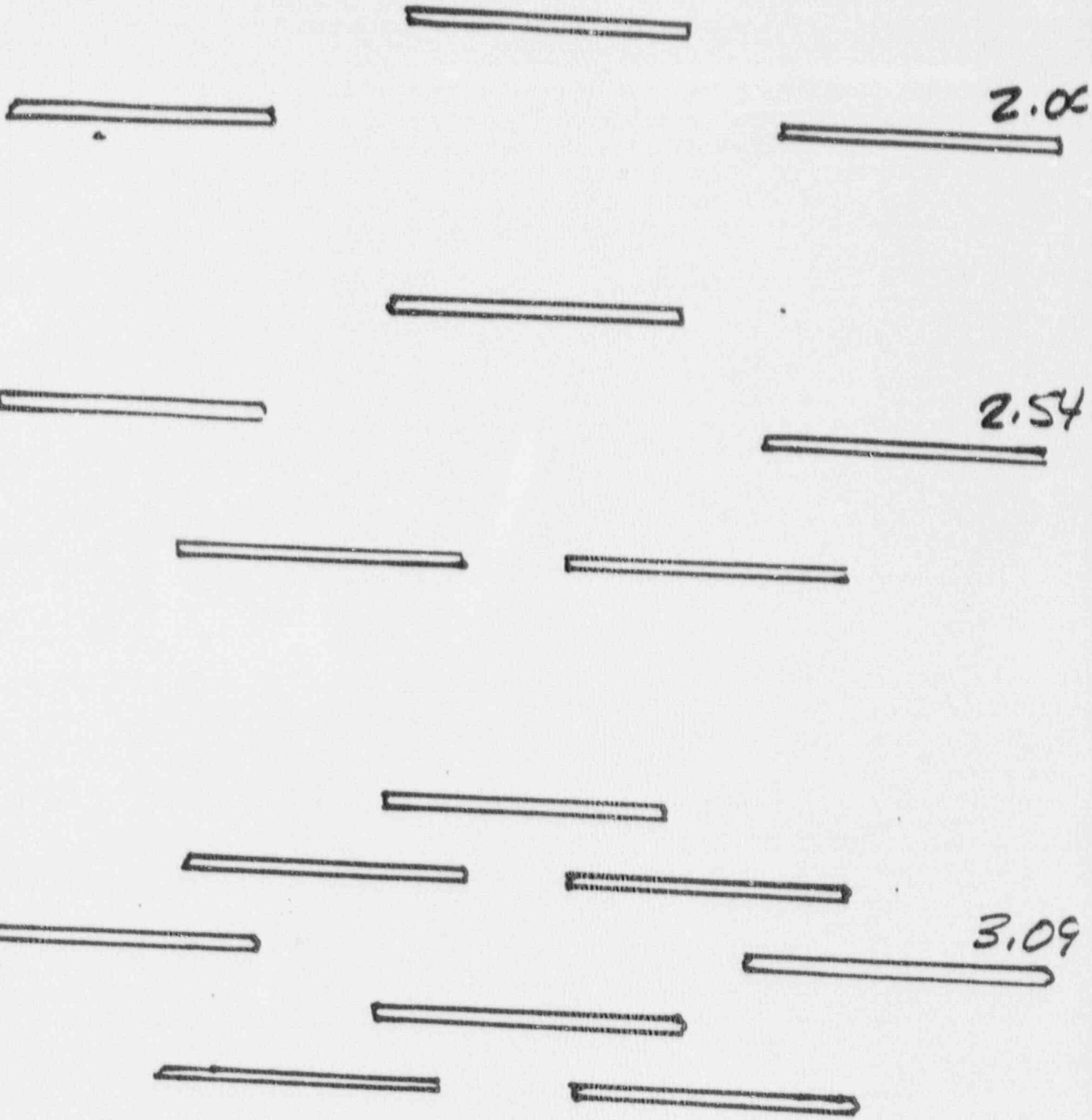
- Feasibility EC Tests Performed
- Voltage Increases with Crack Severity
  - With Increasing Crack Length
  - With Increasing Number of Cracks of Similar Length
  - With Increasing Number of Cracks Around Tube Circumference
  - With Loss of Ligaments

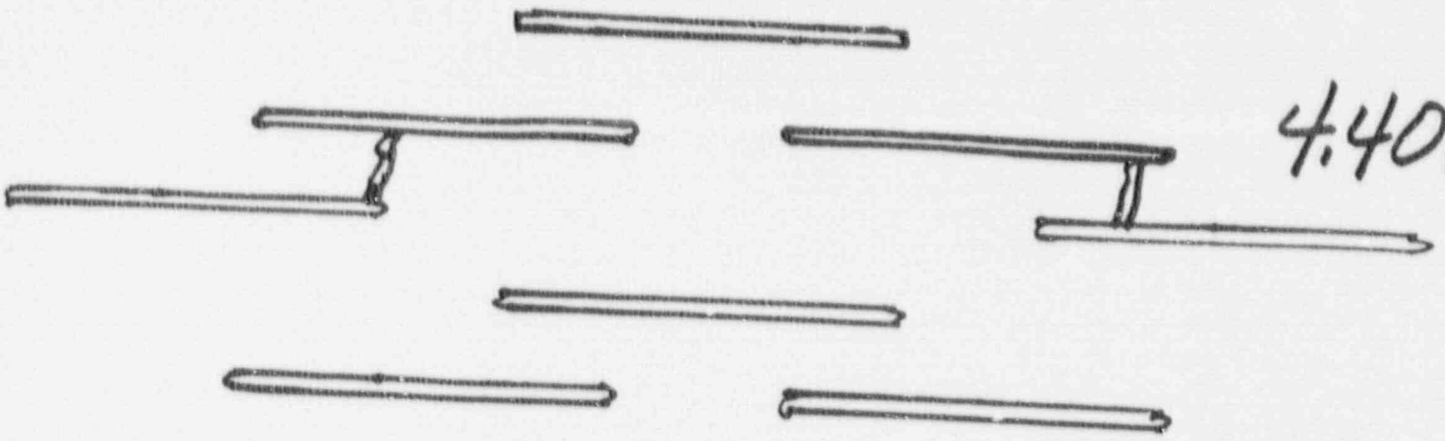
Average Depth Index

- Average Depth (Phase Angle) Used to Simplify Interpretation and Improve Consistency Between Analysts

Average Crack Depth and Crack Network Length (Voltage) Control Ligament Fracture and Thus Leakage Under SLB Conditions


1.93 V
2.77 V
3.83 V
4.21 V
1.97 V
2.30 V
3.59 V
0.75"


2.0
2.54
3.09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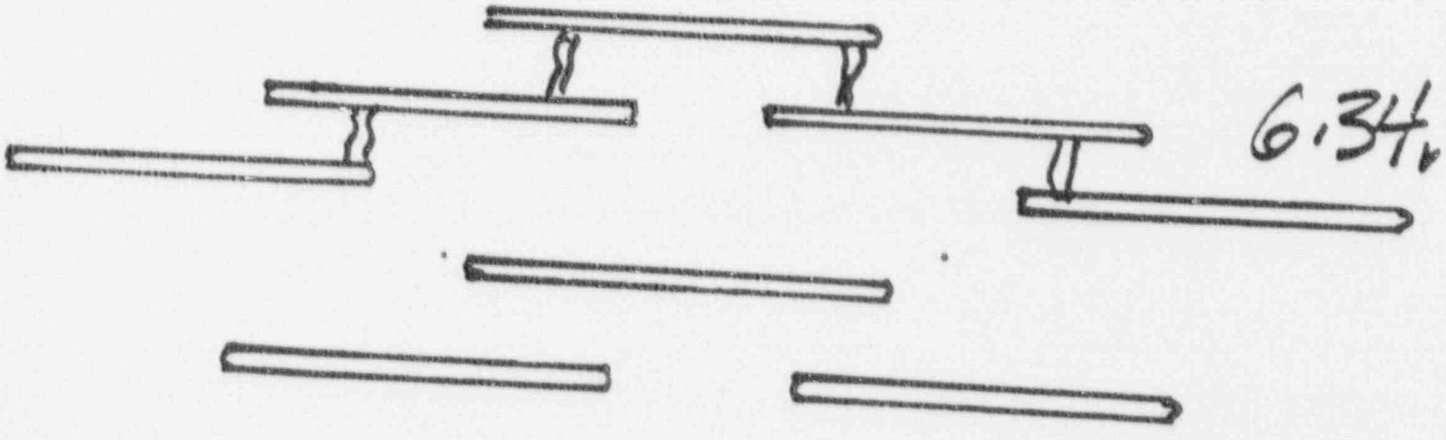

6.34v

EPRI Program
APC for ODSCC at TSPs

NDE Evaluation

- Model Boiler Specimens
- Doped Steam Specimens
- Available Pulled Tube Data

Alternate Plugging Criteria

- Model Boiler Specimens
- Pulled Tube Data
- Field Data for Leaking Tubes

Influence of Tube Denting on Leakage

- Fatigue Specimens
- Doped Steam Specimens

Burst Testing

- Model Boiler Specimens
- Doped Steam Specimens
- EDM Notch Specimens

EPRI Program
APC for ODSCC at TSPs

Pulled Tube and Field Data

- Pulled tube data supports [ ]^{9} volts (up to 100% depth) as acceptable (no leakage)
- Field leakage experience (3 tubes) above [ ]^{9} volts
- Inadequate data in [ ]^{9} volt range
  - Range of data needed from model boiler specimens

Leak Rate Testing of Laboratory Specimens

- Currently insufficient model boiler specimens to confidently establish voltage criteria
  - Difficulty in generating model boiler specimens with thru-wall cracks and [ ]^{4} volts (lower bound of MB leakers)
- SLB to normal operating leak rate ratio bounded by factor of [ ]^{9} volts)
  - Indicative of insignificant crack deformation under SLB conditions
- Tubes cracked [ ]^{9} show no leakage even at SLB conditions (8 specimens)
- Magnetite packed crevices reduce leak rate compared to open crevices (3 specimens)

TABLE 5.1

PULLED TUBE DATA - BURST PRESSURE

Plant	Bobbin Coil Volts	Bobbin Coil Depth	Bobbin Coil Phase	Destructive Exam. Max. Depth	Destructive Exam. Length(1)	Burst Pressure (psi) No Leak	Burst Pressure (psi) Burst
A-2							
B-1							
D-2							

- 9

1. Crack network lengths with through-wall crack lengths in parentheses - destructive exam shows many, small axial cracks

2. N.M. = Not Measured

3. Values in parentheses are estimated tube burst pressures based upon crack morphology obtained from destructive examination metallography. This pressure would be required to obtain a large leak at SLB conditions for these tubes with no leakage at normal operating conditions.

4. Thin, peripheral ligament remaining leads to an effective through-wall length of 0.1".

TABLE 5.3-1

FIELD EXPERIENCE
SUSPECTED TUBE LEAKAGE FOR ODSCC AT TSPs

Plant	Inspection	Bobbin Coil Volts	Bobbin Coil Depth	Comments
B-1	Outage before suspected leak	[		
	Outage following suspected leak			
E	Outage following suspected leakage			
	Outage following			
				] 9

* EC calibration data needed to confirm voltage level.

Notes:

1. Reported voltages were adjusted to normalization in this report of [ ] 9

Figure 5-1

Pulled Tube and Field Bobbin Coil Inspection Data

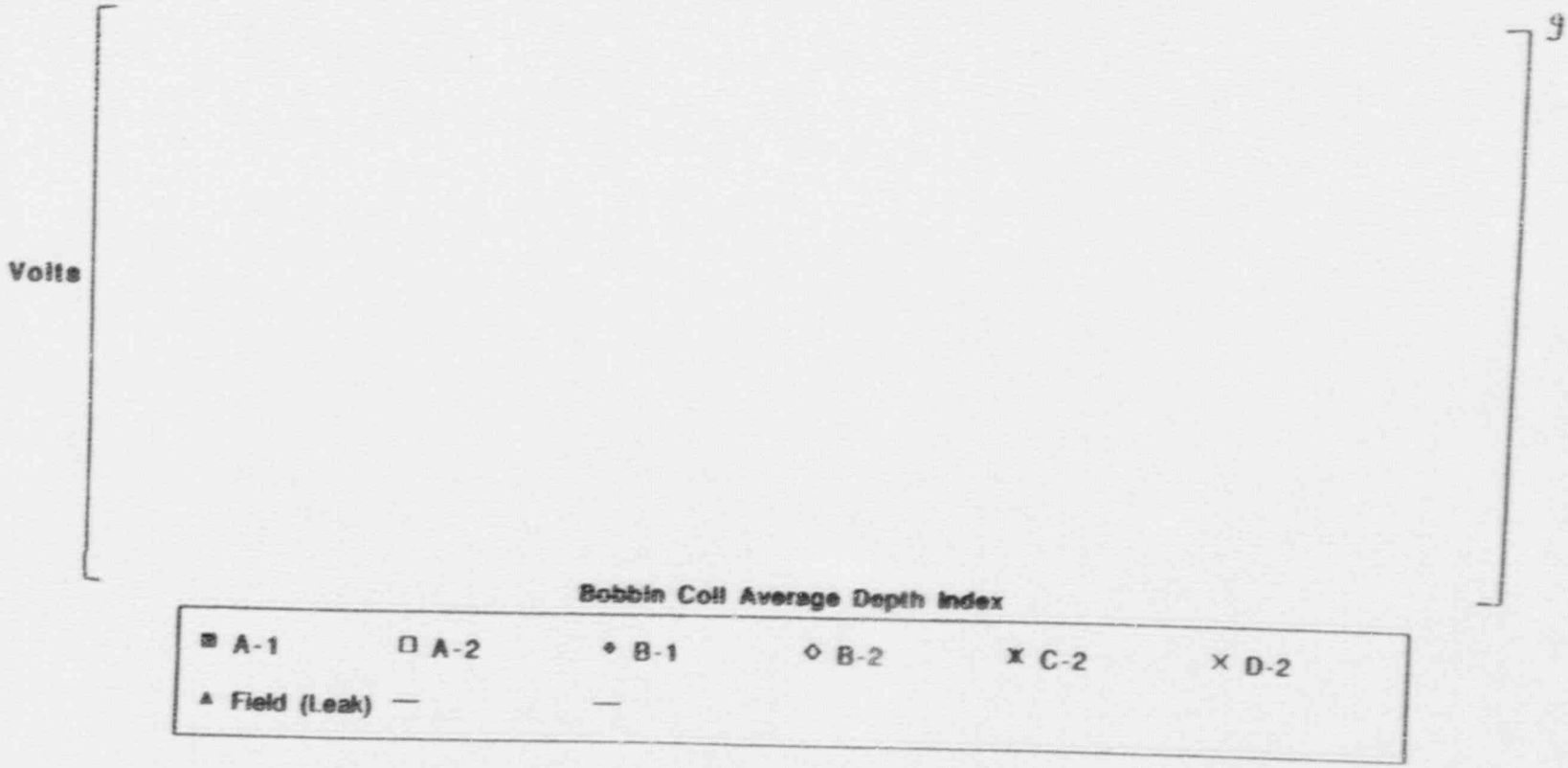
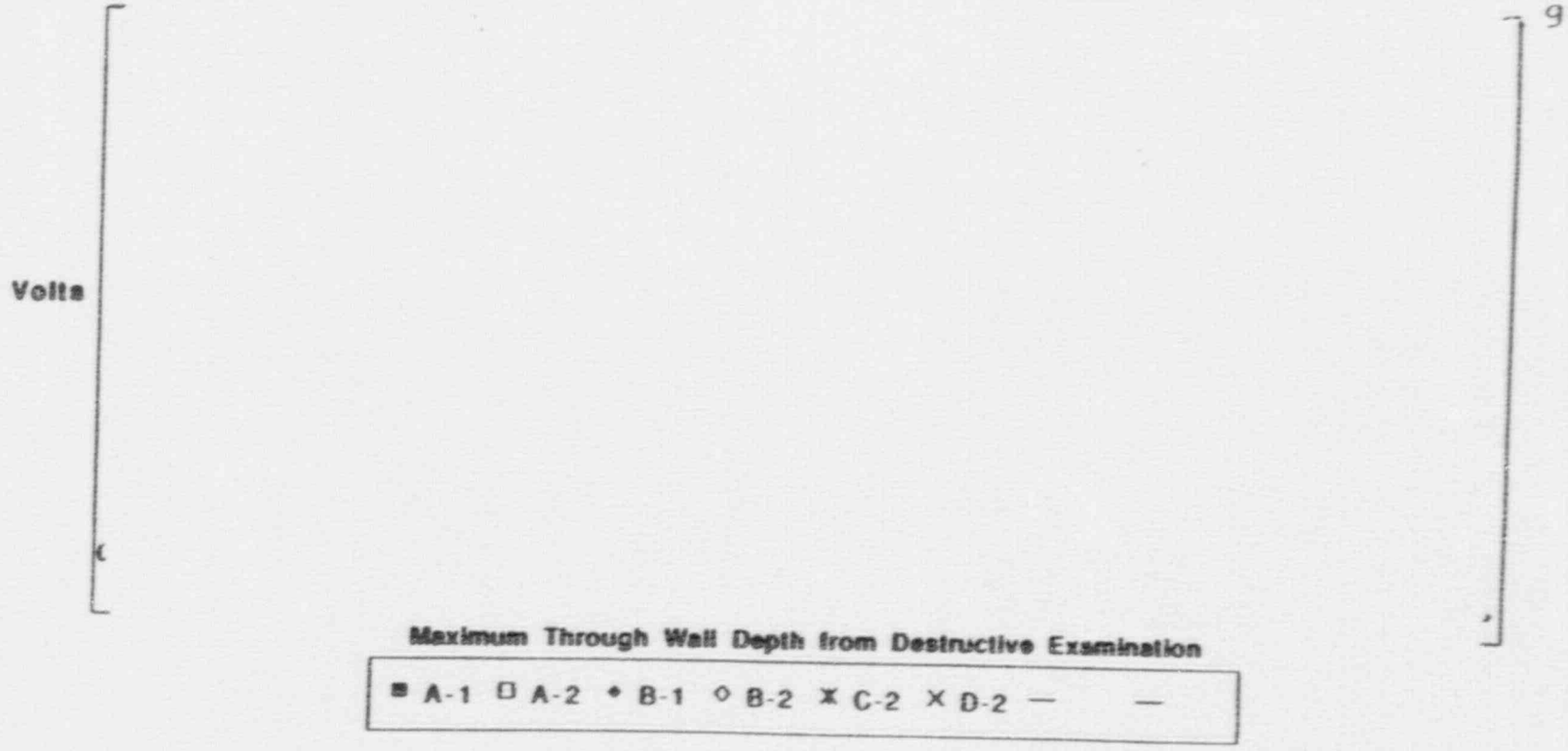
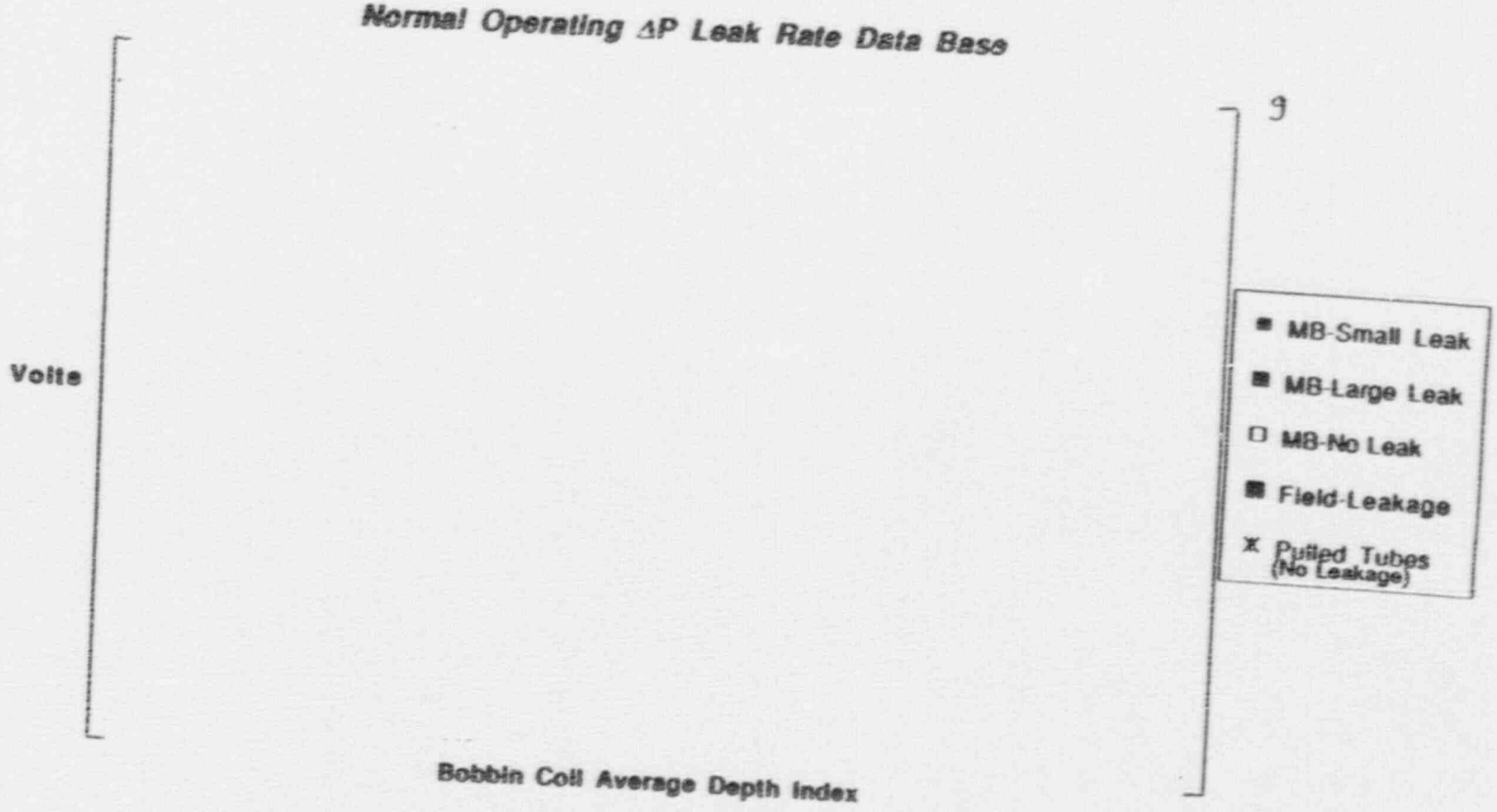


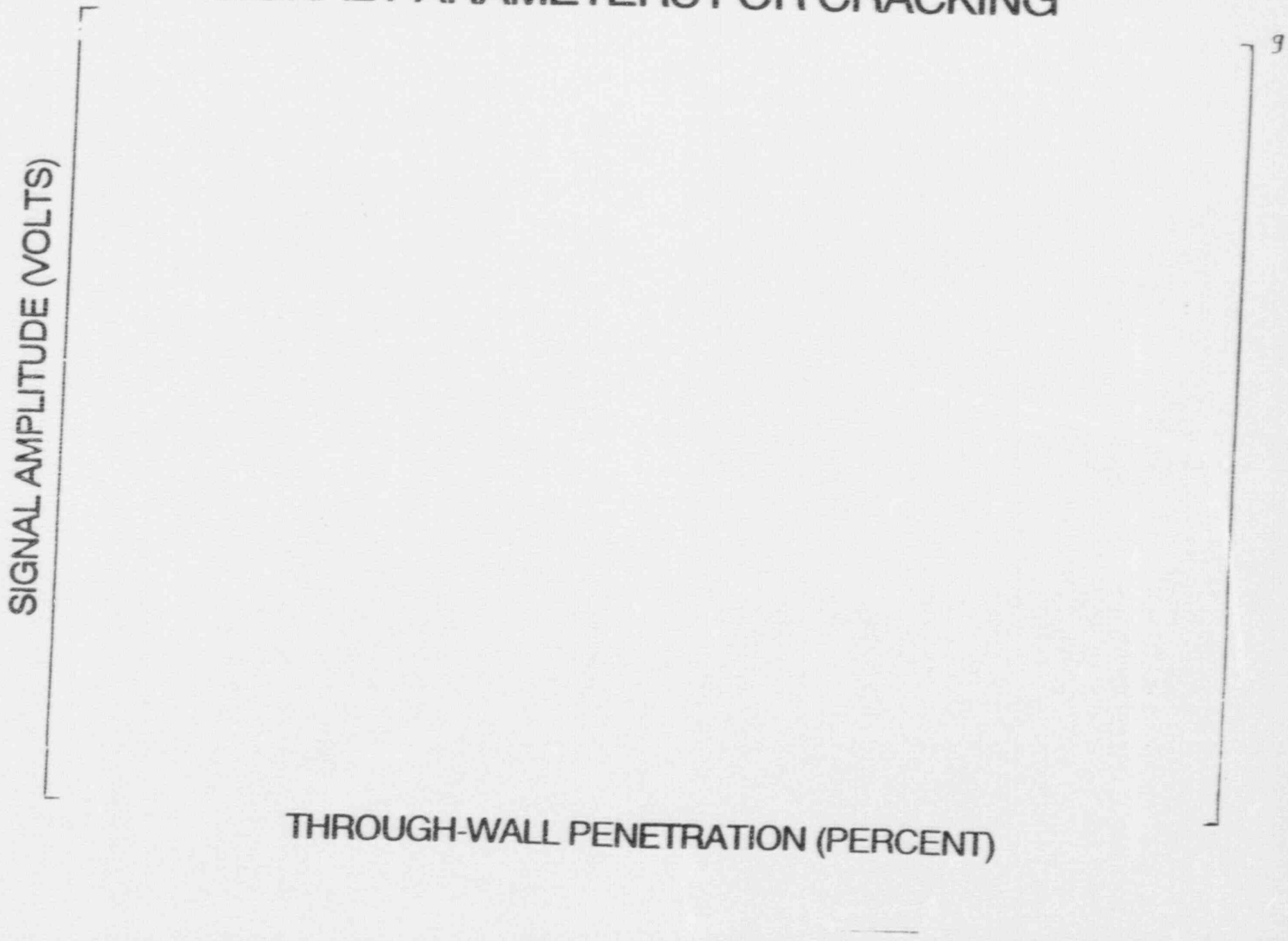
Figure 5-2

Pulled Tube Destructive Examination Data




Normal Operating ΔP Leak Rate Data Base
Volts
Bobbin Coil Average Depth Index
9
MB-Small Leak
MB-Large Leak
MB-No Leak
Field-Leakage
Pulled Tubes
(No Leakage)

SIGNAL PARAMETERS FOR CRACKING



Normal Operating ΔP Leak Rate Data Base

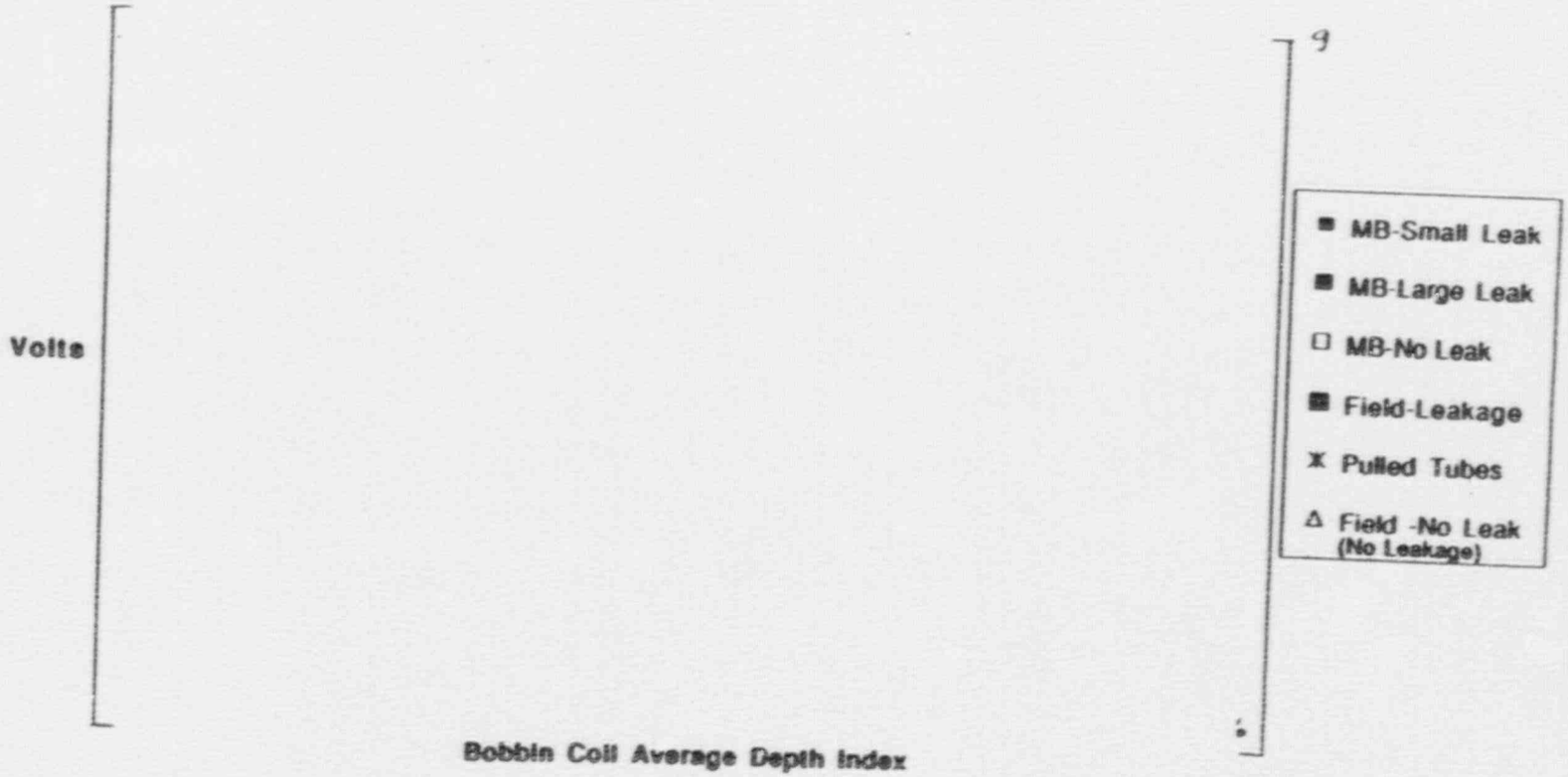


TABLE 11.2

LEAK RATE TEST DATA FOR DENTED TUBE/TSP INTERSECTIONS

Sample I.D.	Dent Size	Dent Voltage	Thru-Wall Crack (in.)	Open Crevice Leak Rate /Vhr	Measured Leak Rate (Vhr) Normal Oper.	SLB
Fatigue Specimens						
FAT1	[					] [9]
FAT2						
FAT3						
FAT4						
FAT5						
FAT6						
FAT7						
FAT8						
FAT9						
FAT10						
FAT11						
FAT12						
ODSCC Specimens						
BW1	[					] [9]
BW3(3)						
BW9						
BW14						

Notes:

1. Fatigue specimen leak rates are calculated leak rates.[ ]

]9

2. Crack network length (includes ligaments)

3. Through wall crack length extended approx. 1/8" otuside TSP.

EZPWSCC In Roll Transitions

Farley 2 Specific Plugging Criteria

Tube Rupture Considerations

Allowable Axial Crack Length

Combined Accident Evaluation

Leakage Rate Calculation

Operating Leakage Rate Limit

EZPWSCC In Roll Transitions

Allowable Axial Crack Length

EPRI NP-6864-L BASIS

CRITICAL CRACK LENGTHS

BURST PRESSURE (PSI)	CRITICAL CRACK LENGTH NO TSC* (INCH)	CRITICAL CRACK LENGTH WITH TSC* (INCH)
1457	0.99	0.99
2650	0.64	0.72
4371	0.35	0.52

* TSC IS TUBE SHEET CONSTRAINT.

EZPWSCC In Roll Transitions

Allowable Axial Crack Length

EPRI NP-6864-L Basis

Normal Operation Pressure Differential

- Limiting Case with Factor of 3
  - $3 \Delta P = 3 (2250-793)$
    $= 3 (1457)$
    $= 4371$ PSI
  - Reference Crack Length = 0.35 inch

Allowable Axial Crack Length, A

- Accounts for growth, EC uncertainty and systematic error, and tubesheet (TS) constraint where applicable
  - A = 0.37 inch with TS constraint
  - A = 0.20 inch without TS constraint

EZPWSCC In Roll Transitions

Allowable Axial Crack Length

Combined Accident Evaluation

- o SSE plus LOCA or SLB/FLB

Primary Stress at Top of Tubesheet

- o Pressure Differential
  - Normal Operation (1457 PSI)
  - SLB/FLB (2650 PSI After Blowdown)
  - LOCA (-793 PSI After Blowdown)
- o Cross-Section Bending Stress

[ ] A, B, C

Cross-section bending stress is well below the magnitude required to have an effect on burst pressure (WCAP 7832-A)

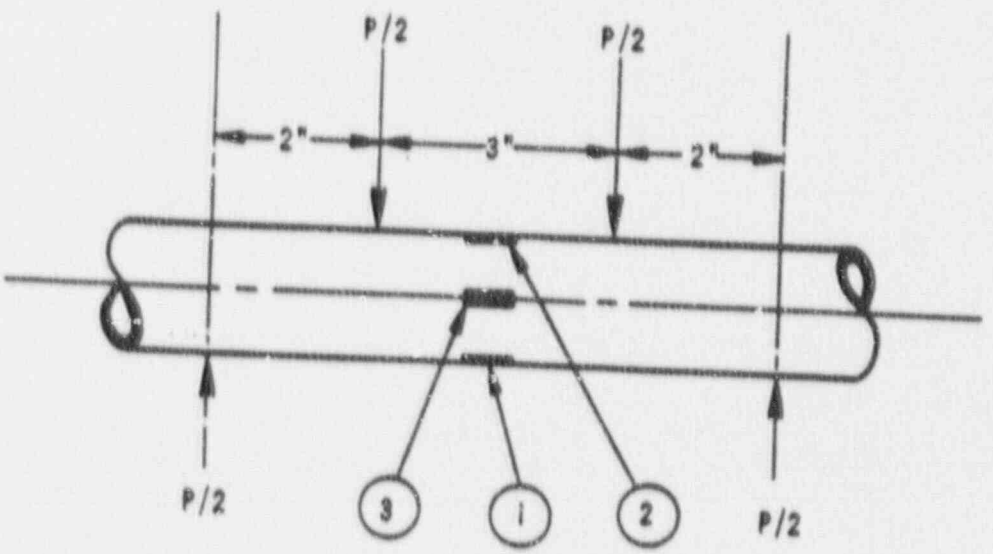
- o [ ] A, B, C

Allowable axial crack length determined on the basis of internal pressure only is justified

COMBINED BENDING AND INTERNAL PRESSURE BURST TESTS
ON TUBES WITH THROUGH WALL SLOTS

[redacted]

A, B, C



Externally Applied Bending Load and Locations of Through Wall Penetrations

EZPWSCC In Roll Transitions

Leakage Rate ... ulation

OVERVIEW

Probabilistic techniques are combined with a deterministic model for leakage from a single axial crack to determine the leakage rate for the distribution of axial crack lengths.

Potential leakage is obtained for all axial cracks detected by RPC inspection above the F* distance with crack length less than allowable.

EZPWSCC In Roll Transitions

Leakage Rate Calculation

Axial Crack Flow Model
(Crackflo)

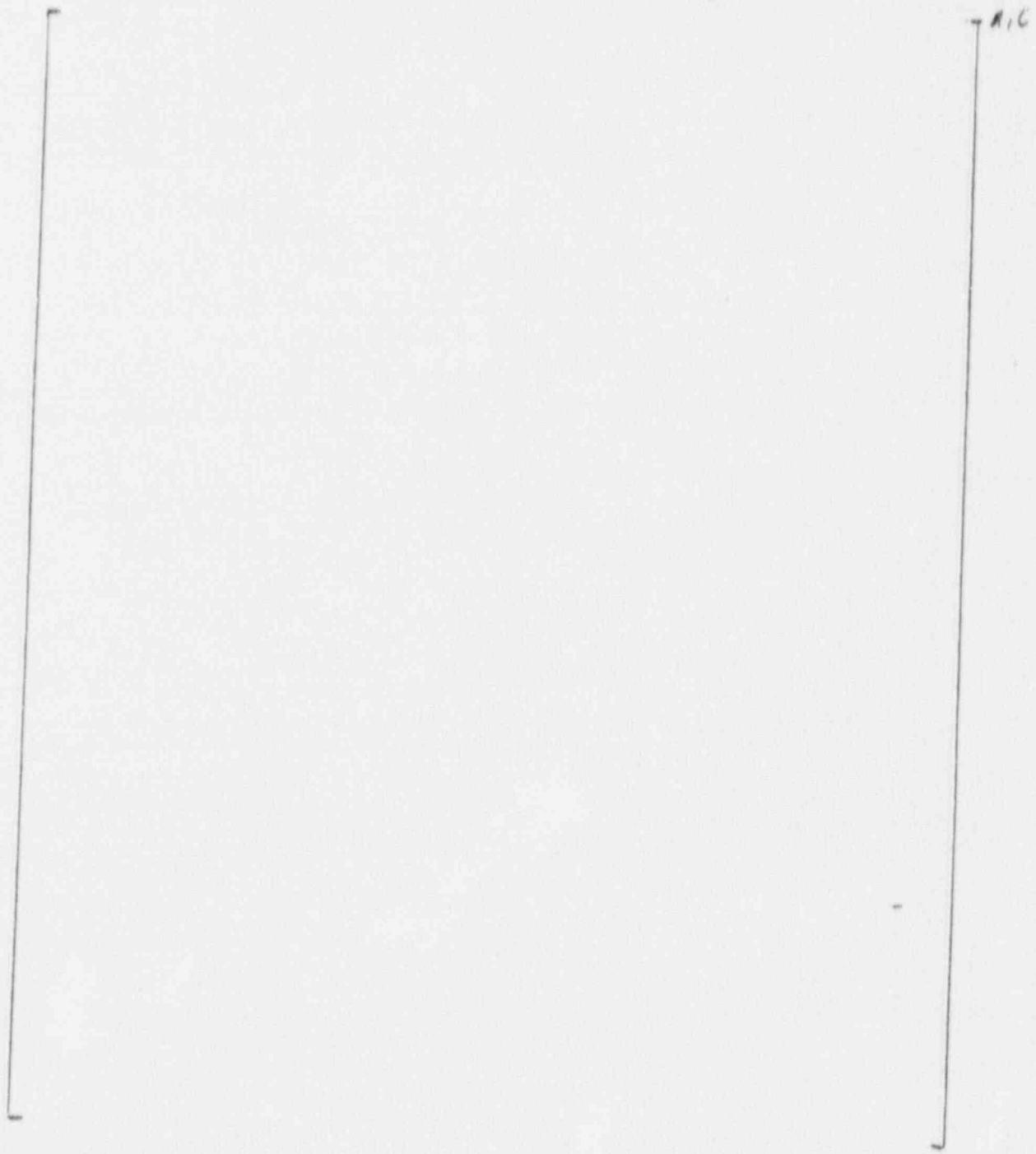
Assumptions

EZPWSCC In Roll Transitions

Leakage Rate Calculation

Axial Crack Flow Model
(Crackflo)

Fluid and Pressure Drop Characteristics



EZPWSCC In Roll Transitions

Leakage Rate Calculation

Axial Crack Flow Model
(Crackflo)

AXIAL CRACK OPENING AREA MODEL

[ ]

[ ] a,c

EZPWSCC In Roll Transitions

Leakage Rate Calculation

Axial Crack Flow Model
(Crackflo)

Solution Procedure

[ ]

[ ]^{a,c}

EZPWSCC In Roll Transitions

Leakage Rate Calculation

COMPARISON WITH EXPERIMENTAL RESULTS

NORMAL PLANT OPERATION

- In general, model yields a good prediction for the trend of leak rate with crack length.

- Excellent agreement between predicted and measured leak rates is shown for fatigue cracks.

- For stress corrosion cracks, greater data scatter is shown.

  - SCC cracks are characteristically small ~ 0.1" long
  - Difficult to define geometrically
  - Susceptible to plugging

COMPARISON BETWEEN PREDICTED & MEASURED LEAK RATES

a,b,c

PREDICTED LEAK RATE (GPM)

MEASURED LEAK RATE (GPM)

EZPWSCC In Roll Transitions

Leakage Rate Calculation

COMPARISON WITH EXPERIMENTAL RESULTS

STEAM-LINE BREAK CONDITIONS

- In general, the model over predicts leak rates for SLB.
- In order to improve prediction capability, empirically based adjustments are made to the model.

[ ] A,C

COMPARISON BETWEEN PREDICTED & MEASURED LEAK RATES

a,b,c

PREDICTED LEAK RATE (GPM)

MEASURED LEAK RATE (GPM)

EZPWSCC In Roll Transitions

Leakage Rate Calculation

PROBABILISTIC METHODOLOGY

A Monte Carlo type evaluation is perfopmed by sampling crack length from a given population together with each of the following normally distributed statistical parameters:

[a, c]

EZPWSCC In Roll Transitions
Leakage Rate Calculation

UNCERTAINTY ANALYSIS

Measured versus predicted values (M vs. P) are fit by [ ]A,C

[ ]A,C

Normal Operation

[ ]A,C

SLB Condition

[ ]A,C

Factors

	1 SIGMA	2 SIGMA
N.O.	[	]A,C
SLB	[	]A,C

MEASURED VS PREDICTED LEAK RATES

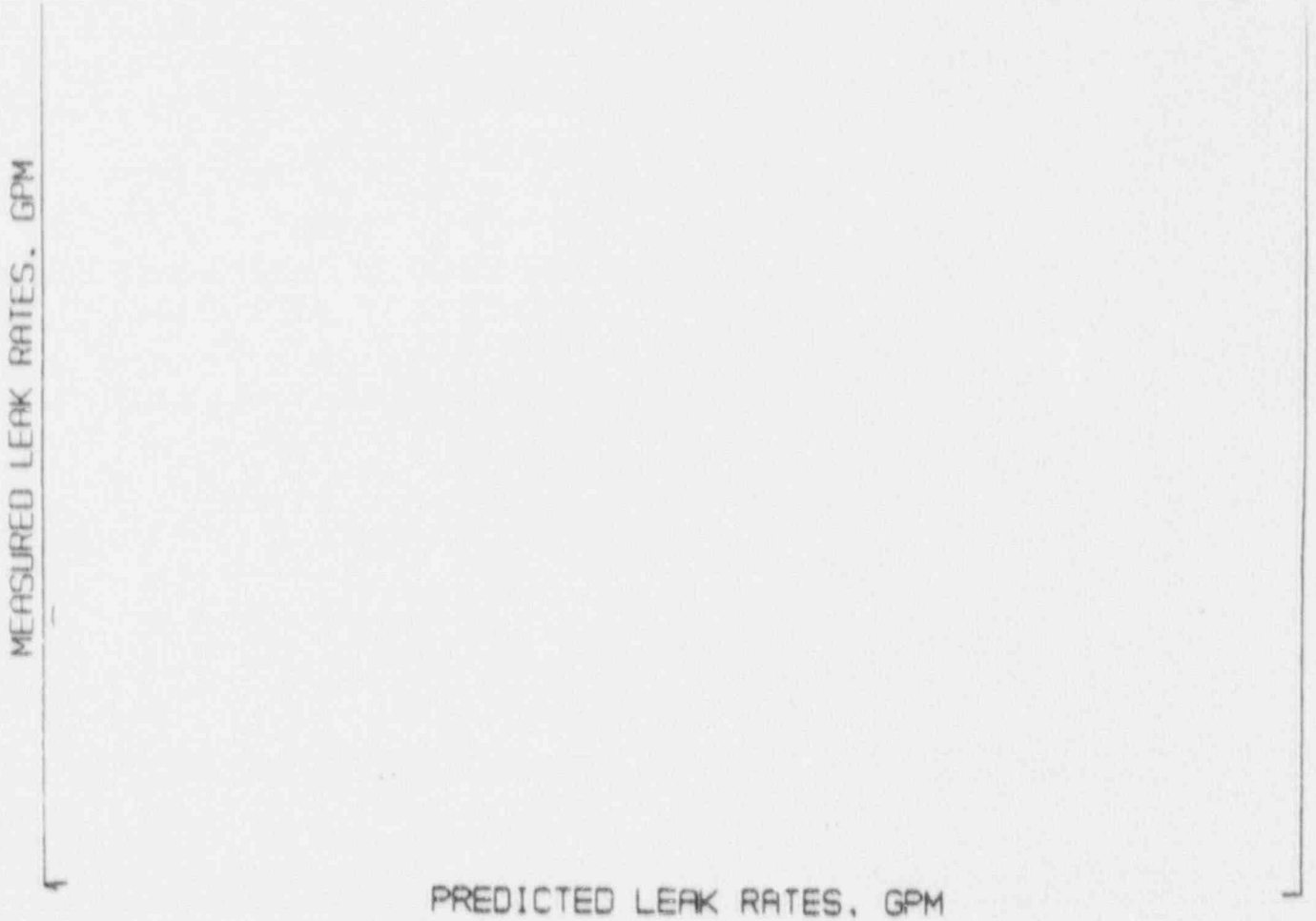
a,b,c

MEASURED LEAK RATE (GPM)

PREDICTED LEAK RATE (GPM)

MEASURED VS PREDICTED LEAK RATES

[a,b,c]



EZPWSCC In Roll Transitions

Leakage Rate Calculation

SLB Leakage Rate Comparison for EPRI Distributions

1000 Cracks from 0 to 0.394 inch (10 mm) in length

Calculation Model	Leak Rate (GPM) A	Leak Rate (GPM) B
EPRI/Laborelec		
K Curve 1	[	] 9
K Curve 2		
Crackflo		
Nominal	[	] a, b, c
Nominal + 2 Sigma		
Nominal + N Sigma		

EZPWSCC In Roll Transitions

Operating Leakage Rate Limit

EPRI NP-6864-L Basis

Reasonable assurance of leak before break is achieved with a [ ]^{a,c} GPM leakage rate limit.

Historically, axial cracks in roll transitions have exhibited low leakage, even no leakage in some cases. Accordingly 100% EC inspection is performed with MRPC probes to completely characterize the condition of the bundle in affected regions.

The combination of 100% MRPC inspection and the [ ]^{a,c} GPM leakage rate limit constitute a defense in depth and assure control of tube bundle strength and leakage integrity.

EZPWSCC In Roll Transitions
Operating Leakage Rate Limit

Leak Before Break

Assuming [ ] gpm leak rate limit and minimum burst capability

Nominal RT leakage vs crack length

- With TS constraint, 3 P burst capability is assured; 0.52 inch vs 0.40 inch, burst vs leak.

-2 sigma RT leakage vs crack length

- With TS constraint, SLB burst capability is assured; 0.72 inch vs 0.60 inch, burst vs leak.

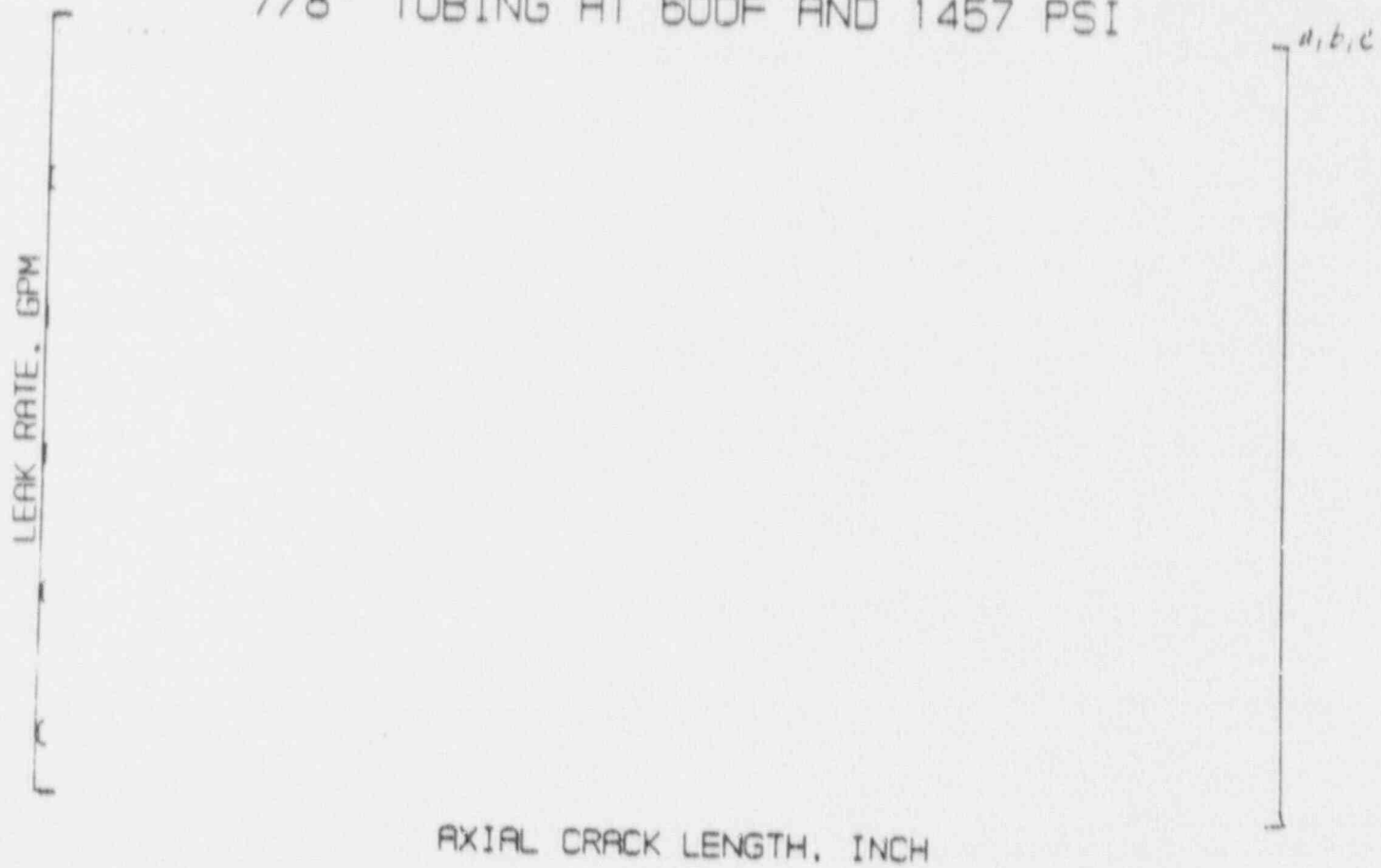
Without TS Constraint

- SLB burst capability is assured for -2 sigma RT leakage vs crack length; 0.64 inch vs 0.60 inch, burst vs leak.
- Growth and uncertainty allowances limit this condition to an EOC length of 0.35

LEAK RATE VS AXIAL CRACK LENGTH

EXPANSION ZONE ROLL TRANSITION

7/8" TUBING AT 600F AND 1457 PSI



FARLEY UNIT 2

SALIENT ASSUMPTIONS USED TO DETERMINE ALLOWABLE PRIMARY-TO-SECONDARY LEAK RATE FOLLOWING A STEAMLINE RUPTURE

- PRIMARY COOLANT INITIAL IODINE ACTIVITY:
  1% DEFECTS

- SECONDARY COOLANT INITIAL ACTIVITY:
  0.1 MICRO Ci/GM D.E. I-131

- LOCATION OF POTENTIAL TUBE LEAKS:
  TUBE SHEET

- PARTITION COEFFICIENTS:
  SG IN RUPTURED LOOP - 1.0
  SG's IN INTACT LOOPS - 0.1

- STEAM RELEASE FROM INTACT LOOPS (0-2 HRS.)
  479,000 LBM

- SITE BOUNDARY x/Q : 7.6 E-4 SEC/M^3

FARLEY UNIT 2

RESULTS OF ALLOWABLE LEAK RATE EVALUATION

DOSE ACCEPTANCE CRITERIA:

2 HOUR SITE BOUNDARY THYROID
DOSE LESS THAN 30 REM

ALLOWABLE LEAK RATE:

40 GPM PER GENERATOR

FARLEY UNIT 2

STEAM GENERATOR OPERATING HISTORY

PRESENTED BY
D. D. MALINOWSKI
MANAGER, STEAM GENERATOR DIAGNOSTICS
NUCLEAR SERVICE DIVISION
WESTINGHOUSE ELECTRIC CORPORATION

ALABAMA POWER COMPANY/U.S.N.R.C./
WESTINGHOUSE ELECTRIC CORPORATION
MEETING

ROCKVILLE, MD
NOVEMBER 5, 1990

FARLEY UNIT 2

Prior S/G Operating History

J. M. Farley Unit 2
Tube Plugging Chronology
By Cause

Date	Cause	S/G A	S/G B	S/G C	Total
Preservice		3	1	-	4
6/81	Visual Leaker	1	0	0	1
10/82	Row 1 (Prev.)	92	94	94	280
	F. O.	3	0	0	3
	Total	95	94	94	283
9/84	Leak (HL) Below TSP 7	1	0	0	1
	F. O.	0	2	0	2
	Total	1	2	0	3
1/85	AVB-Wear	8	0	0	8
	Tube Pull	1	0	0	1
	Prev. Tubesheet PWSCC	3	0	0	3
	Other	1	0	0	1
	Total	13	1	0	14
4/86	AVB-Wear	1	1	0	2
	Tubesheet PWSCC	8	5	27	40
	O.D. TSP SCC	2	9	17*	28
	Total	11	15	44 *(2 PULLED)	70
11/87	Tubesheet PWSCC	4	9	16	29
	O.D. TSP SCC	6	24	44	74
	Free-Span	0	0	0	3
	AVB-Wear	3	2	0	2
	Above Tubesheet	0	0	1	1
	Total	13	35	61	109
4/89	Tubesheet PWSCC	11	3	2	16
	O.D. TSP SCC	0	8	2*	10
	AVB-Wear	0	1	0	1
	Total	11	12	4	27

*(2 PULLED)

J. M. FARLEY UNIT 2
STEAM GENERATOR
TUBE PLUGGING SUMMARY

PLUGGING DATE	TUBES PLUGGED S/G A	S/G B	S/G C	TOTALS INCREMENTAL	CUMULATIVE
PRE-SERVICE	1	1	0	2	2
8/80	2	0	0	2	4
6/81	1	0	0	1	5
10/82	95	94	94	283	288
9/84	1	2	0	3	291
1/85	13	1	0	14	305
4/86	11	15	44	70	375
11/87	13	35	61	109	484
4/89	11	12	4	27	511
TOTALS	148 (4.4%)	160 (4.7%)	203 (6.0%)		511 (5.0%)

FARLEY UNIT 2

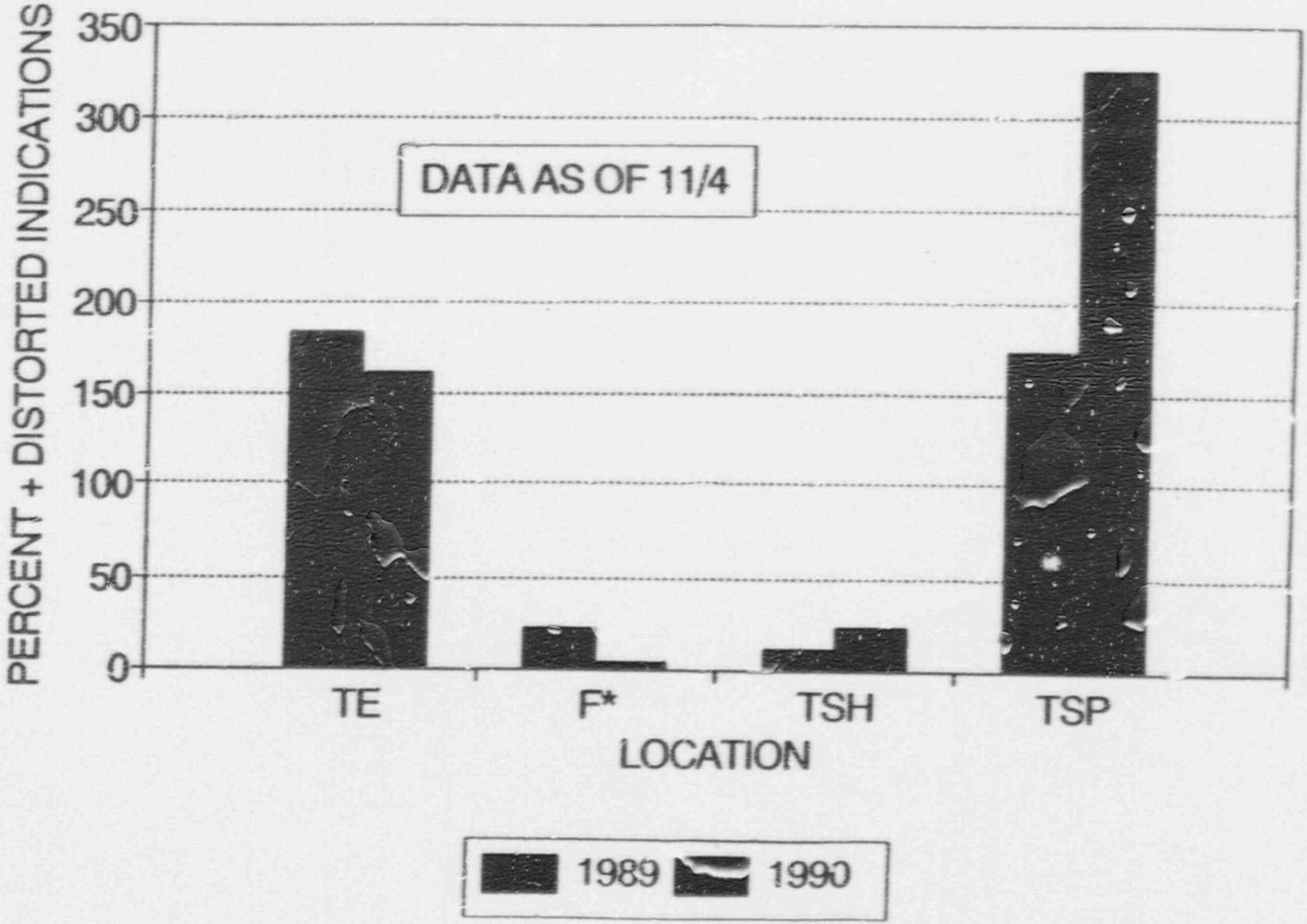
Current Inspection Results

FARLEY UNIT 2

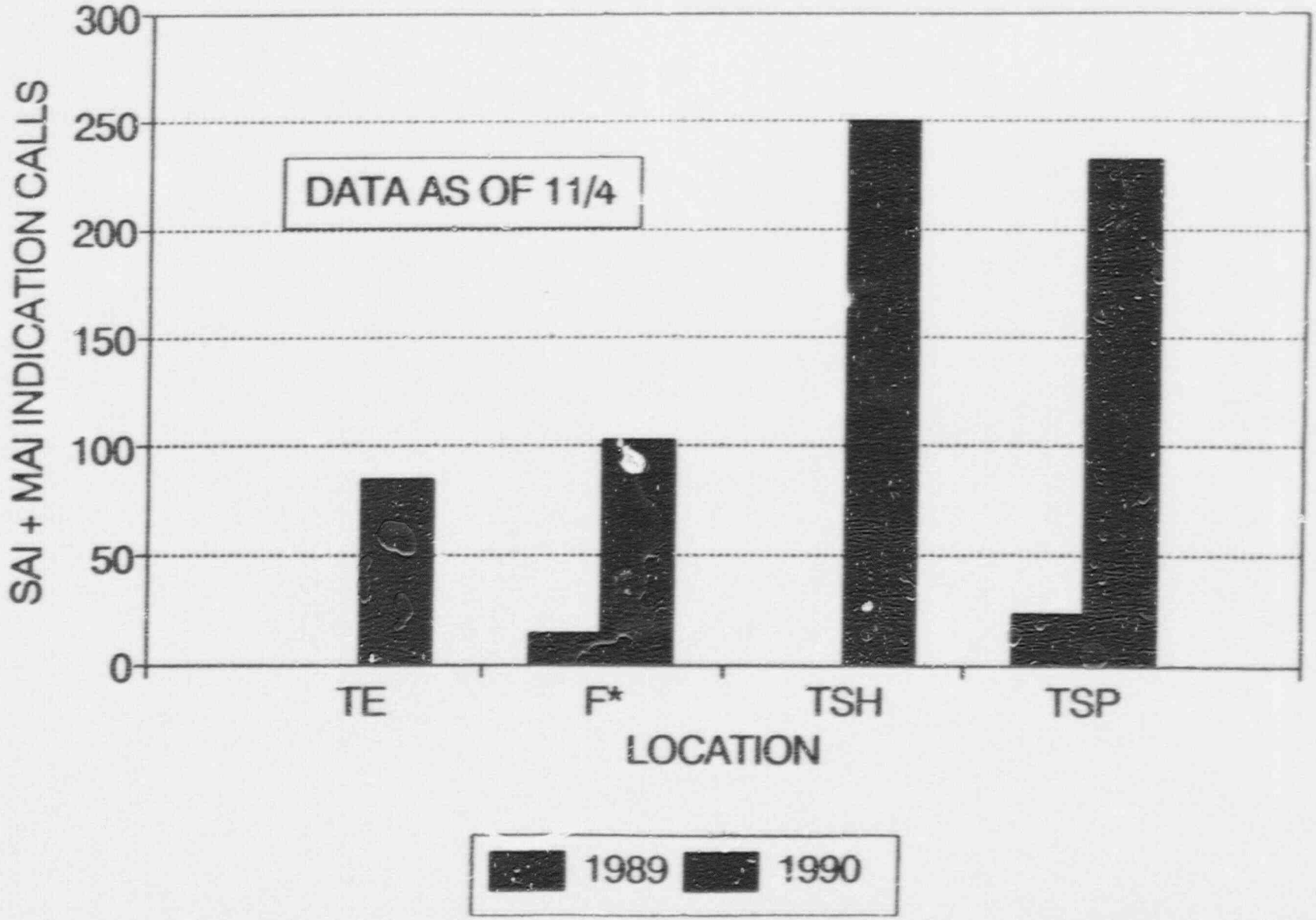
S/G EDDY CURRENT INSPECTION PROGRAM
OCTOBER 1990 OUTAGE

PROBE AND EXTENT	TUBES INSPECTED					
	S/G A		S/G B		S/G C	
	HL	CL	HL	CL	HL	CL
BOBBIN FULL LENGTH	3240	274	3228	276	3185	279
RPC TUBESHEET	3240	-	3228	-	3185	-
RPC AT TSPs	82	-	81	2	195	-
RPC U-BEND	92	-	92	-	94	-
BOBBIN U-BEND (POST HEAT TREAT)	92	-	92	-	94	-

FARLEY UNIT 2 BOBBIN INDICATION CALLS
ALL STEAM GENERATORS

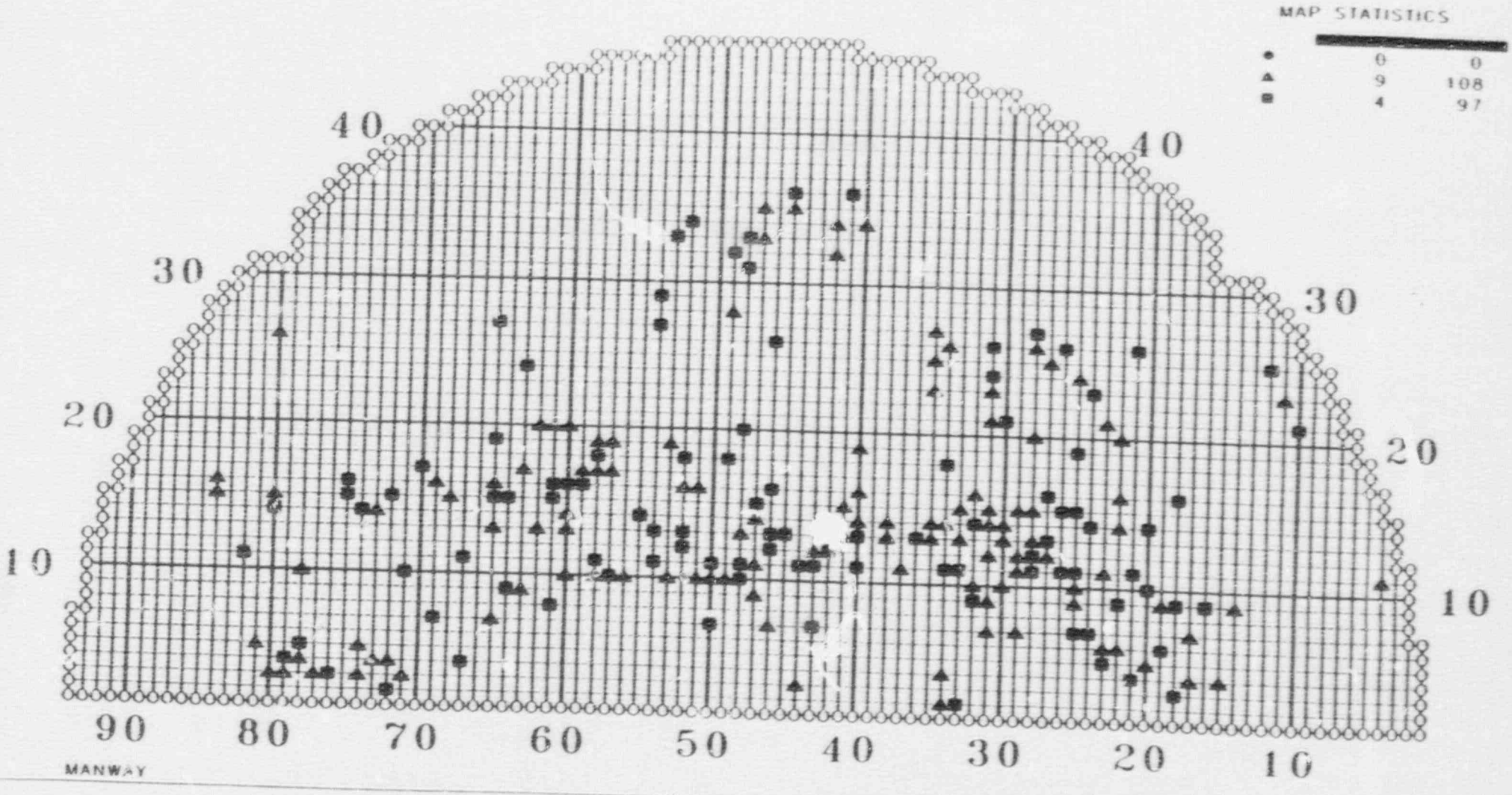


FARLEY UNIT 2 RPC INDICATION CALLS
ALL STEAM GENERATORS



FARLEY UNIT 2 S/G A 11/2 (0400) DATA

TUBESHEET INDICATIONS



○ >= 40%

△ MAI

□ SAI

[·] F·

▒ Top of Tubesheet

STEAM GENERATOR INFORMATION SYSTEM (C) WESTINGHOUSE ELECTRIC CORP 1990 DATE PLOTTED 11/ 2/1990

FARLEY UNIT 2
DETERMINATION OF AXIAL CRACK LENGTHS

SOURCE OF DATA: RPC RESULTS

APPLICATION: TUBE/TUBESHEET ROLL TRANSITION

METHOD:

1 ESTABLISH ROTATIONAL PITCH - *USE MACHINED NOTCHES ON CALIBRATION STANDARD*

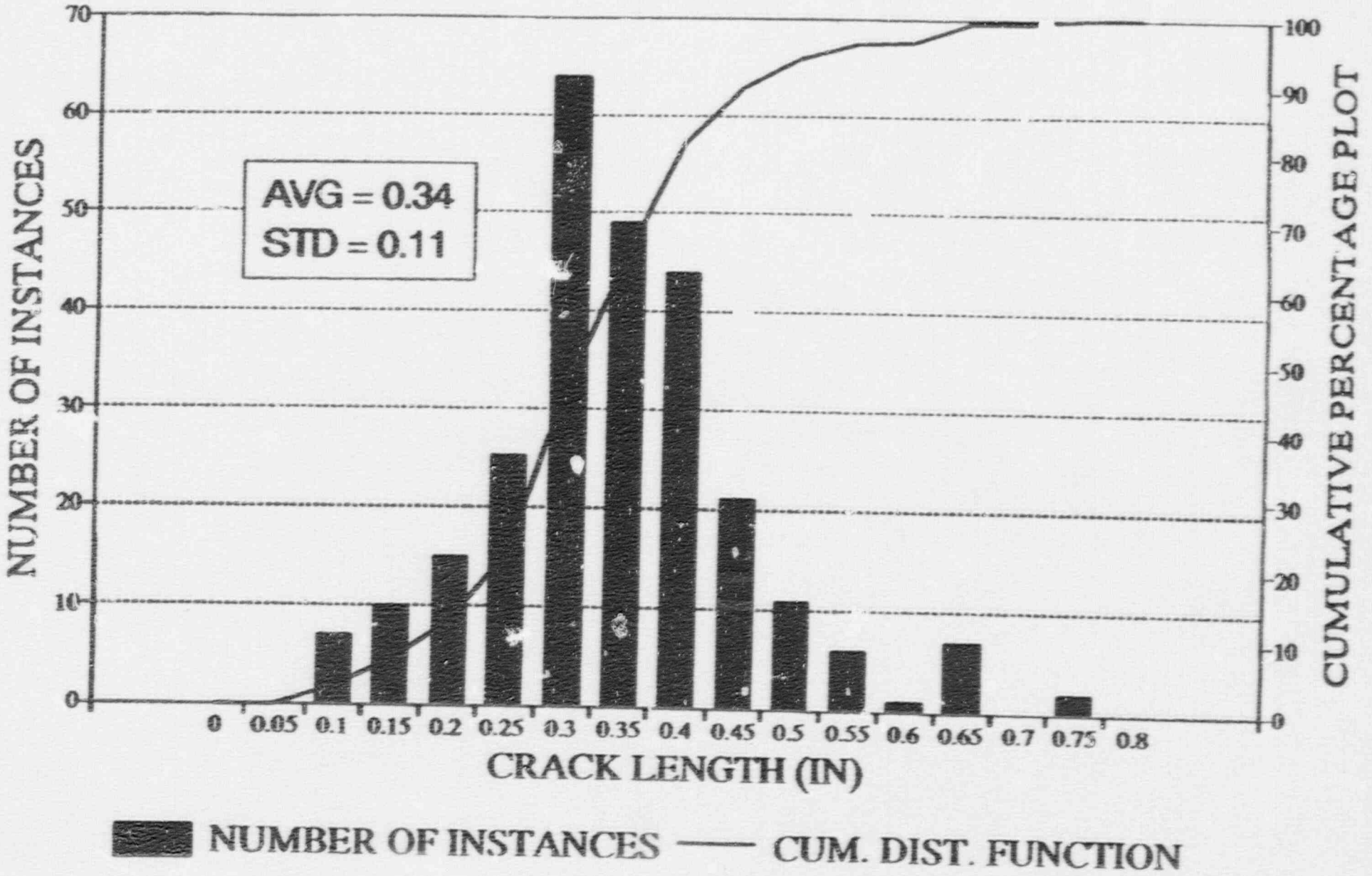
2 DETERMINE NUMBER OF "HITS" *(VERTICAL DEPARTURE FROM NULL EXHIBITING FLAW LIKE FEATURES. USE MOST ACCURATE OF PSEUDO-ISOMETRIC RPC PLOT, EXPANDED STRIP CHARTS OR LISSAJOUS FIGURES)*

3 CALCULATE AXIAL LENGTH - *MULTIPLY ROTATIONAL PITCH BY NUMBER OF "HITS". IMPLICITLY ADDS 1/2 PITCH TO BEGINNING AND END OF EACH INDICATION*

ADDITIONAL CONSIDERATION:

CORRECTION FOR ELECTROMAGNETIC FIELD SPREAD OF COIL IS NOT APPLIED AT PRESENT SINCE MORPHOLOGIES OF INDICATIONS ARE NOT KNOWN ACCURATELY.

FARLEY 2 CRACK LENGTH STATISTICS
DATA AS OF 11/5 (1500)



CRACK LENGTH MEASUREMENT UNCERTAINTY a_{NDE} (EPRI Report NP-6864-L Draft)

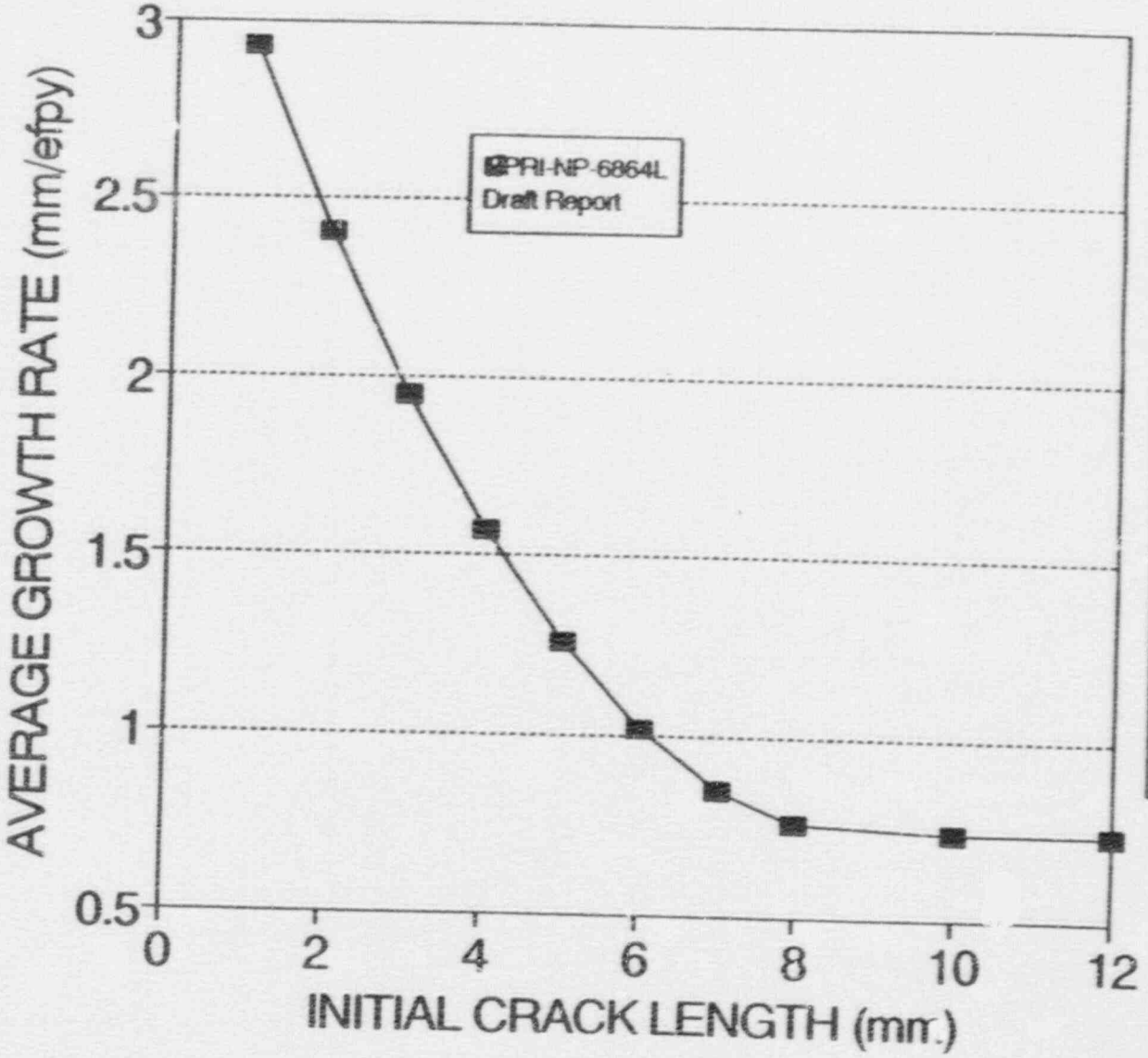
EPRI crack length measurement is the sum of the systematic error and the random error.

Systematic Error = True crack size - NDE crack size
(True crack size measured by metallography or other acceptable method.)

Random Error = Expected NDE crack size - lower bound NDE crack size

a_{NDE} = 0.12" (3.04 mm) for 7/8" tubing

AVERAGE CRACK GROWTH RATES BASED ON KISS-ROLL DATA



Consecutive measurements of crack lengths divided by the time elapsed between measurements yields an estimate of the rate of crack length growth

Farley 2 results from RPC data in 1990 cannot be compared to prior results since tubes with visible cracks in the area of interest were plugged in prior outages.

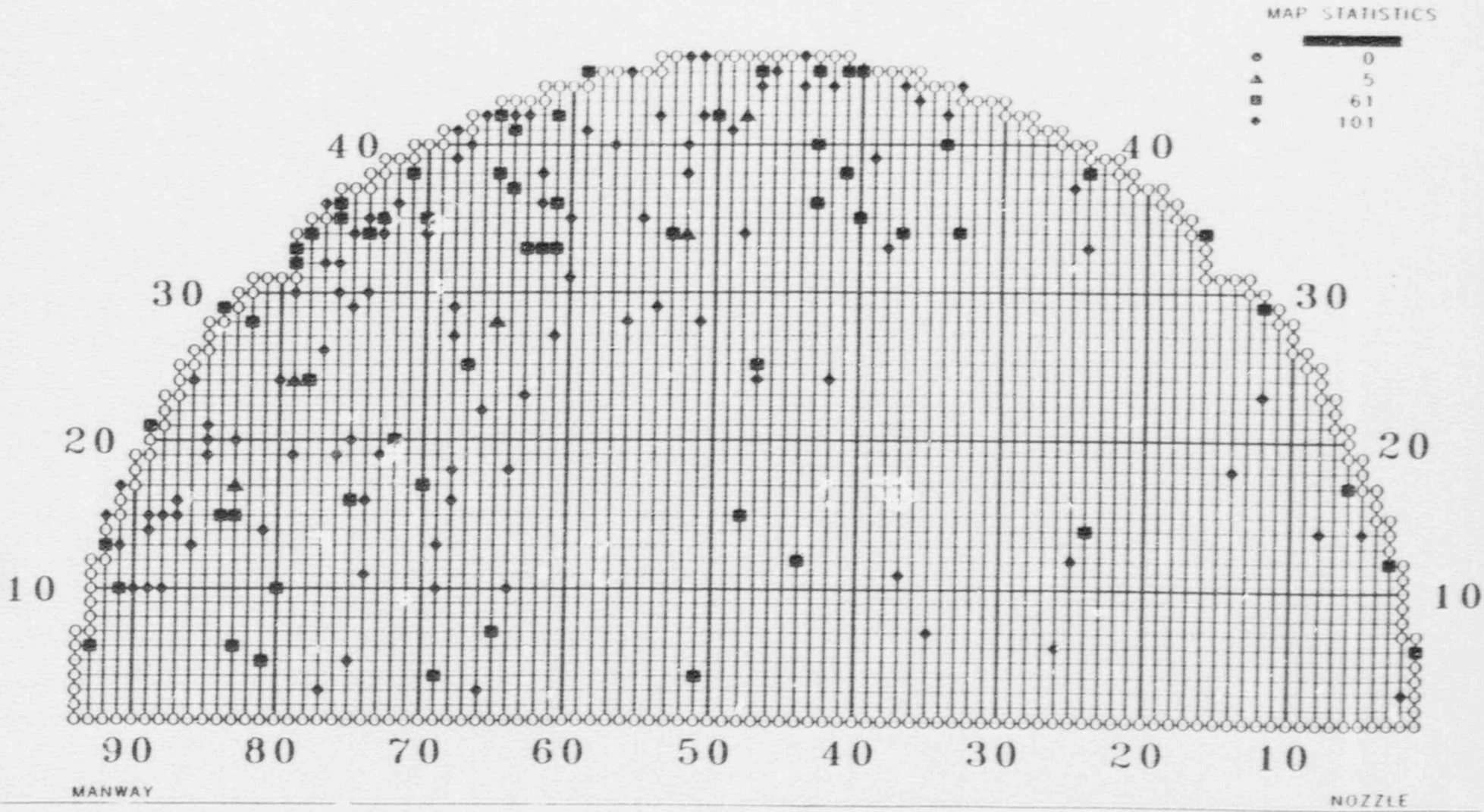
EPRI study provides an estimate of average crack growth rates for various observed lengths in the base inspection.

Growth rate is observed to have an inverse relationship to crack length.

EPRICRAK.WQ2

FARLEY UNIT 2 S/G C 11/4 (040J) DATA

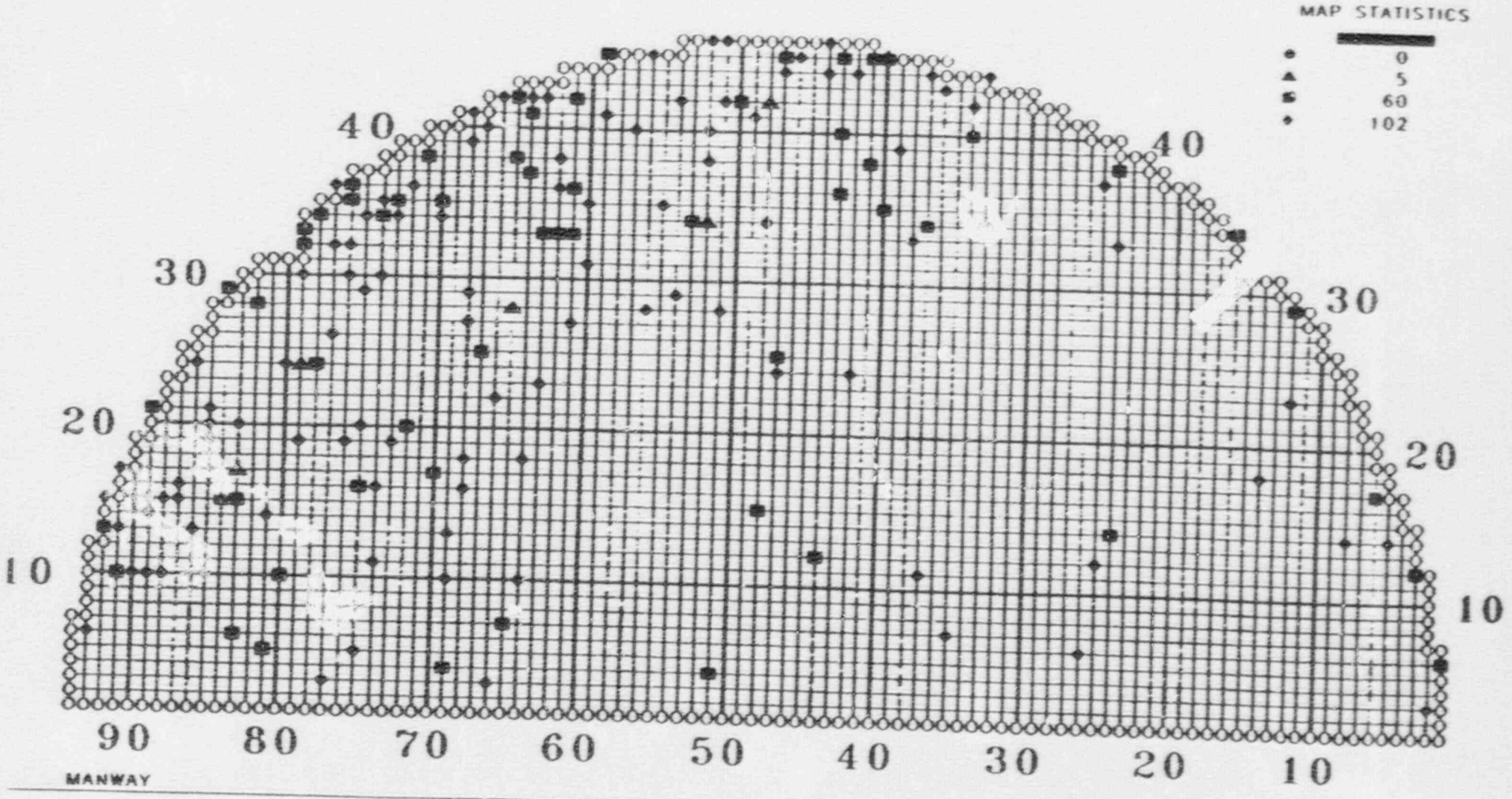
SUPPORT PLATE/AVB INDICATIONS



STEAM GENERATOR INFORMATION SYSTEM (C) WESTINGHOUSE ELECTRIC CORP 1990

DATE PLOTTED 11/ 4/1990

FARLEY UNIT 2 S/G C 11/5 DATA
SUPPORT PLATE/AVB INDICATIONS

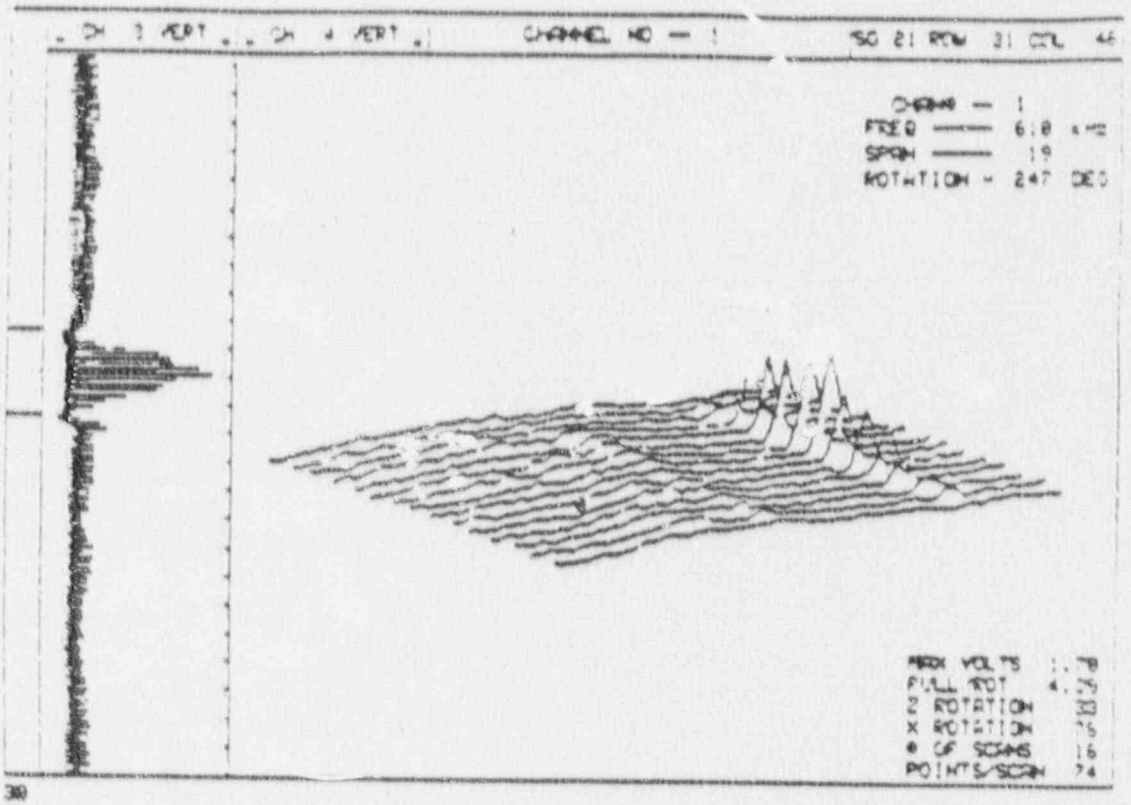


STEAM GENERATOR INFORMATION SYSTEM (C) WESTINGHOUSE ELECTRIC CORP. 1990

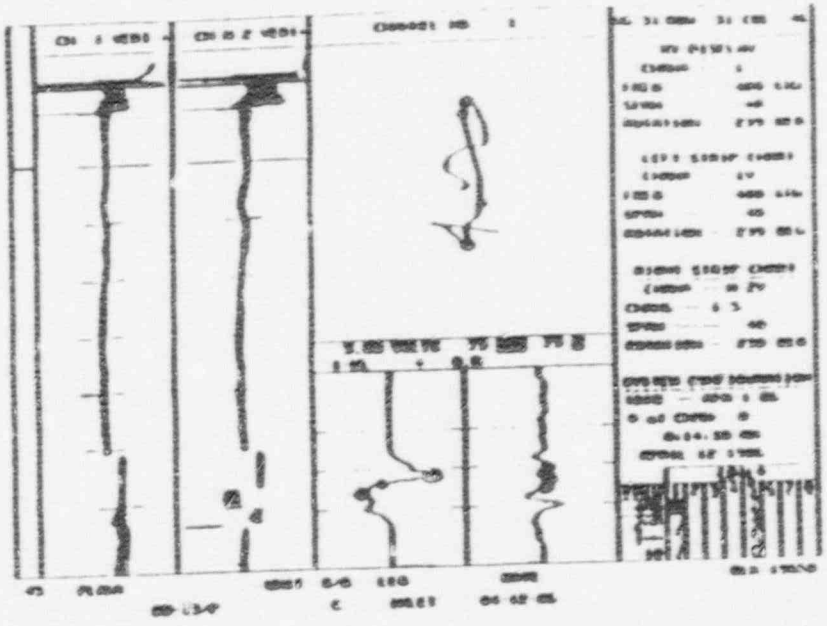
Table IIa

Summary of Examination Results or Farley Unit 2 SG C Tube Removal 4th R

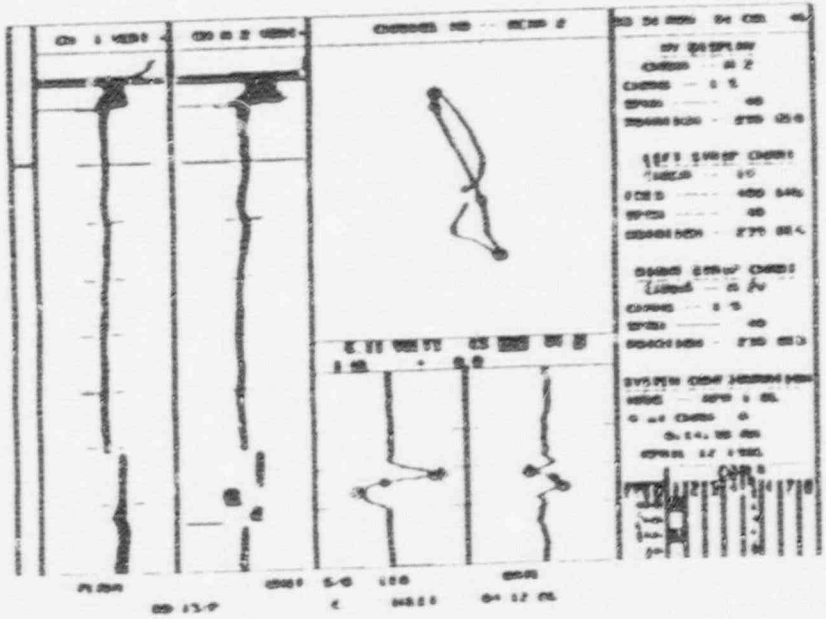
Tube/Location	Field (Bobbin)	Destructive Examination Results
R31C46 1st Sp	81%	OD surface intergranular axial crack. 83% throughwall in one cross section and 100% in another. Some secondary more shallow cracks on OD periphery away from primary crack.



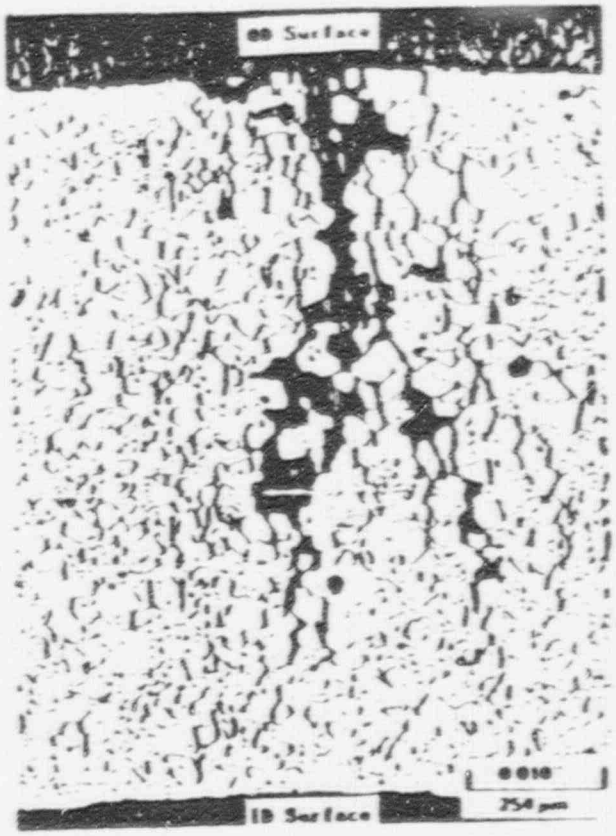
RPC Display for Tube R31C46 Steam Generator C



79%



81%

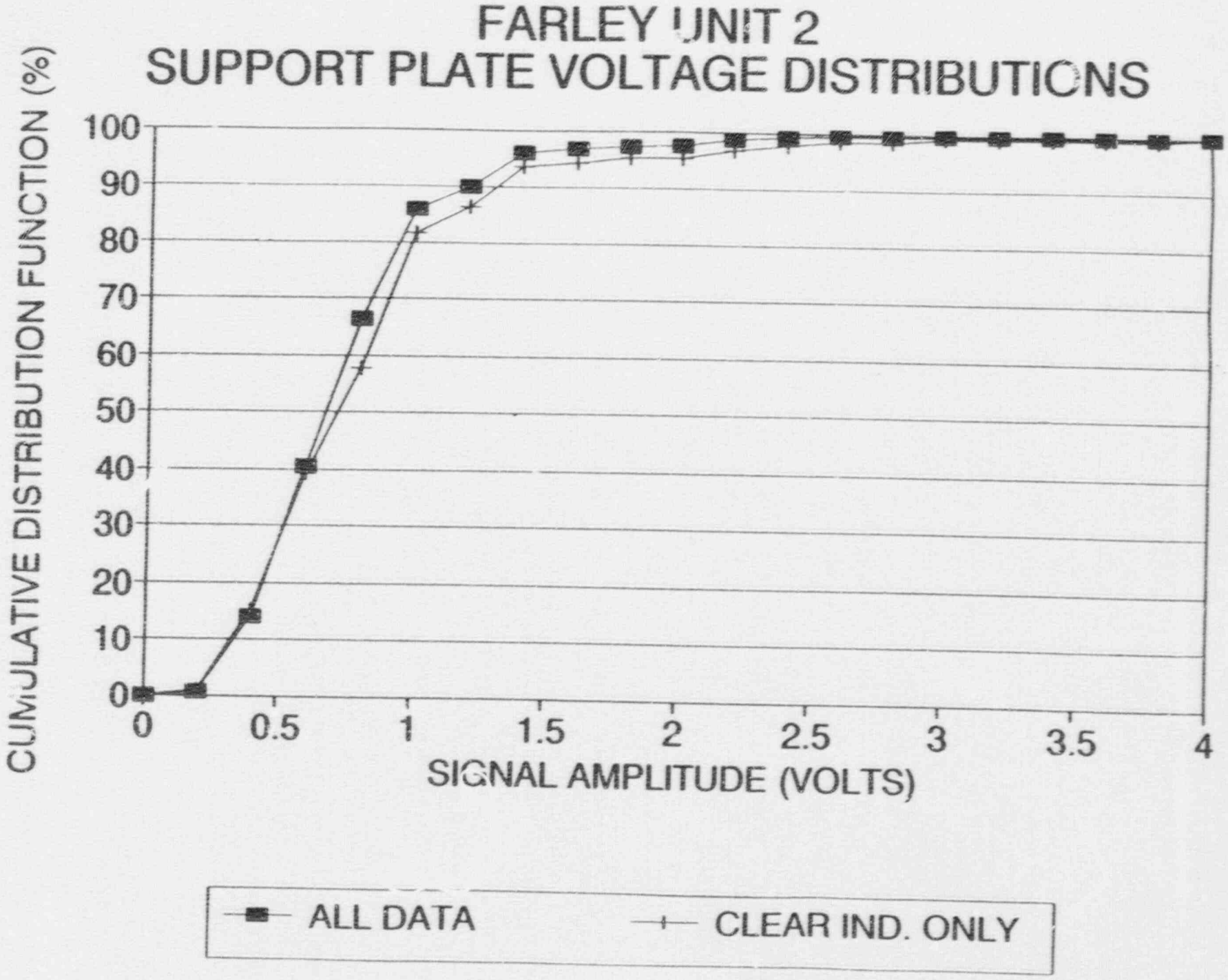


Area A

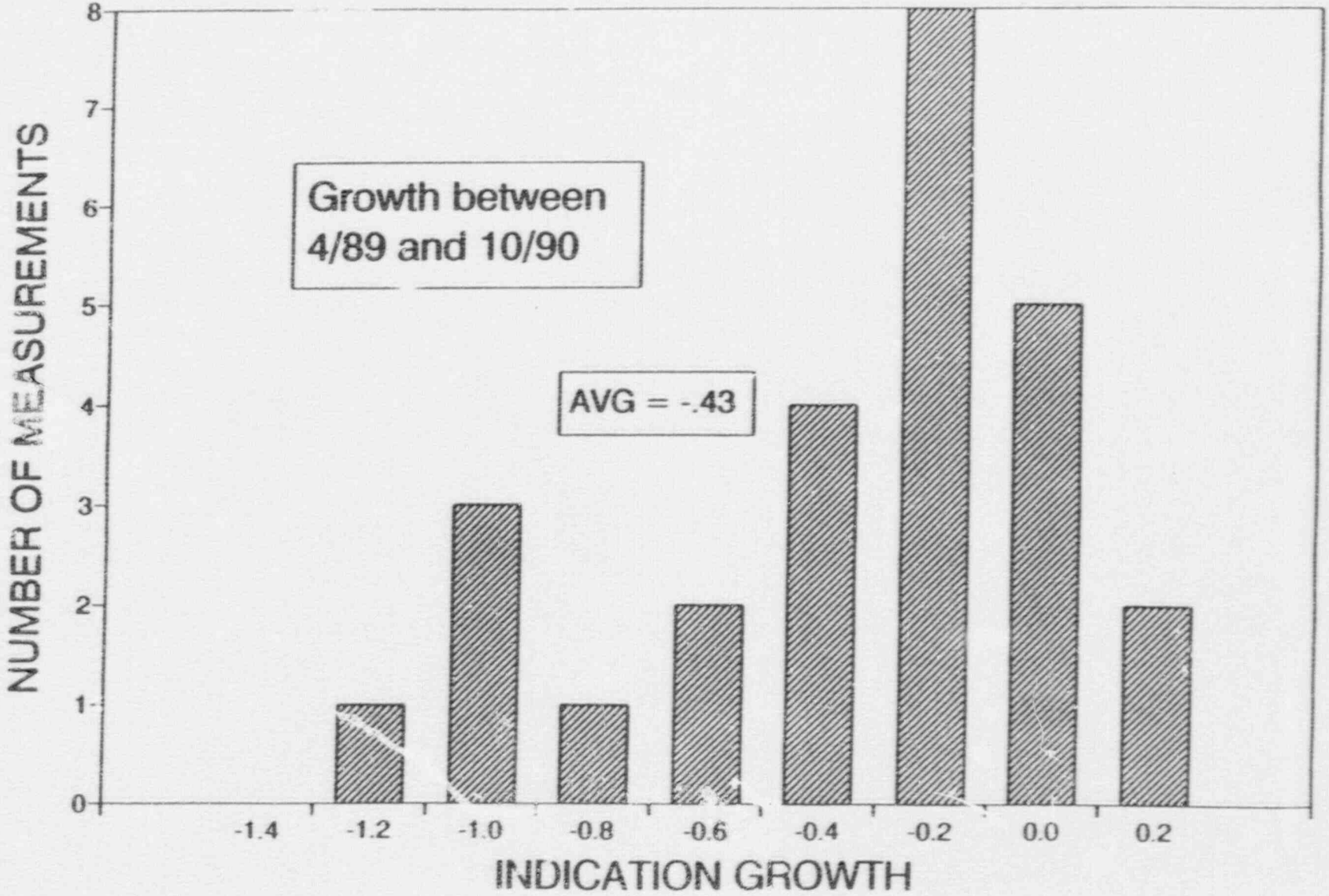
Mag. 100X

Figure — Major crack in tube Section 4 (first support plate region). Crack here extends approximately 80% through wall. It is branched and intergranular. Some grains are missing. Crack profile is one of stress corrosion.

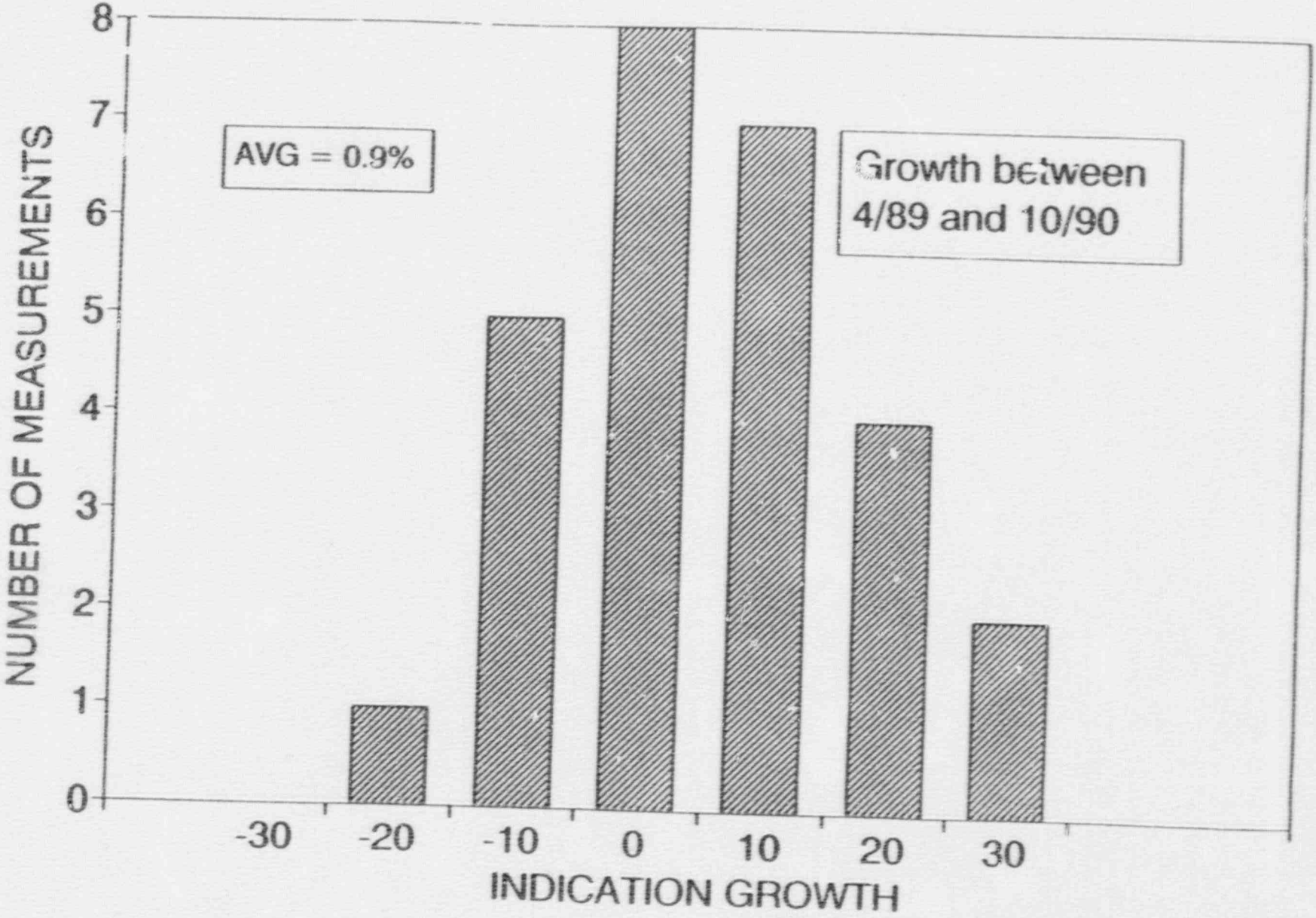
Tube R31C46 TSP IHL 4/86
Metallography Deepest Penetration is 100%


FARLEY UNIT 2
SUPPORT PLATE VOLTAGE DISTRIBUTIONS
CUMULATIVE DISTRIBUTION FUNCTION (%)
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
SIGNAL AMPLITUDE (VOLTS)
ALL DATA
CLEAR IND. ONLY

FARLEY UNIT 2 S/G A SUPPORT PLATE INDICATION GROWTH RATE (V)



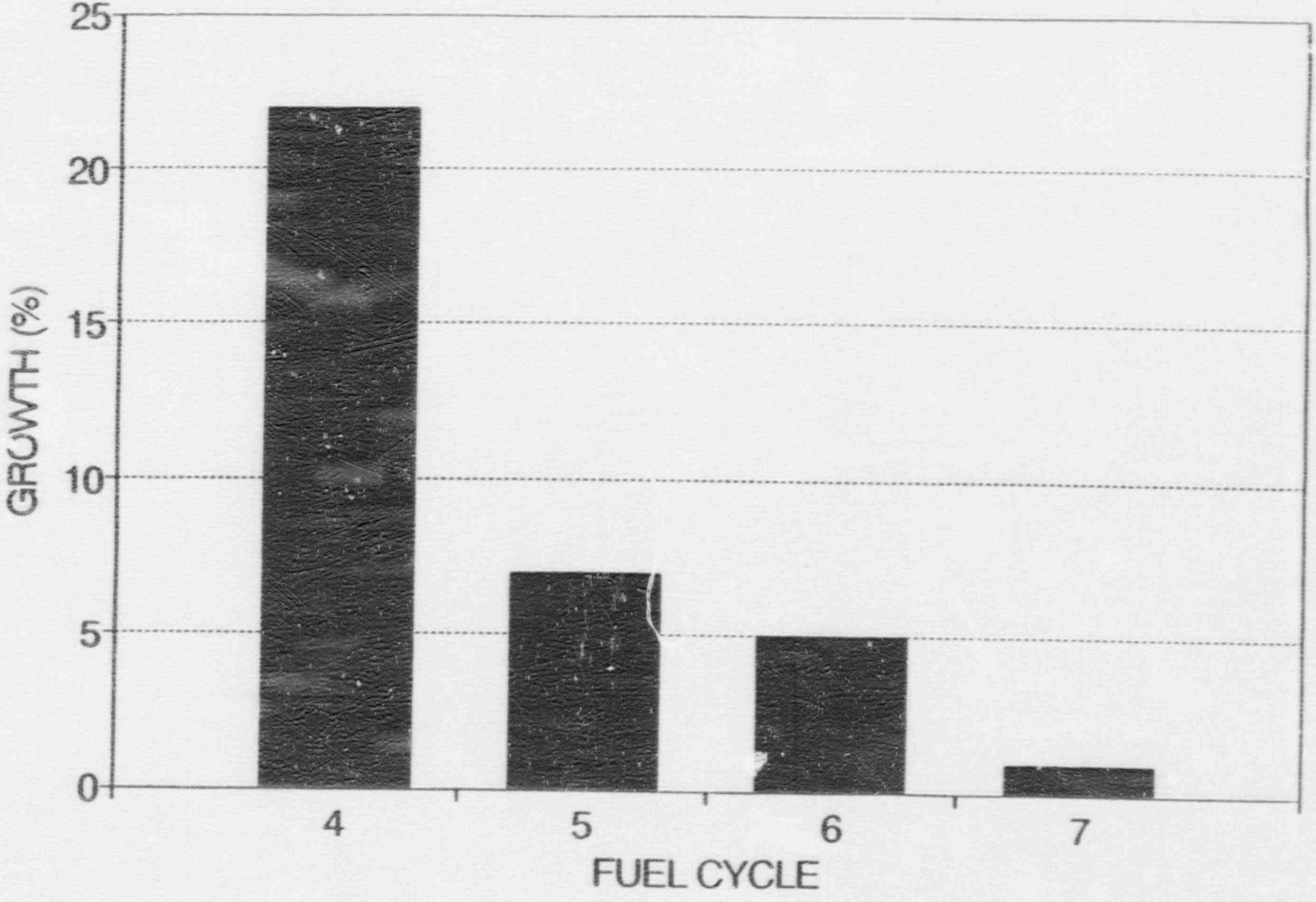
FARLEY UNIT 2 S/G A SUPPORT PLATE INDICATION GROWTH RATE (%)



FARLEY UNIT 2
GROWTH RATES FOR
TSP LEVEL ODSCC

OPERATING PERIOD	CYCLE	ECI GROWTH
1985-1986	4	22%
1986-1987	5	7%
1987-1989	6	5%
1989-1990	7	<1%

FARLEY UNIT 2
GROWTH RATES FOR TSP ODSCC



Farley -2 1990 Outage
Proposed Bases for Tube Plugging

PWSCC at Roll Transitions

- o Limited application of EPRI Program Plugging Criteria
  - Demonstration to develop operating experience with crack length based criteria
- o Proposed demo of EPRI criteria
  - Leave in service a limited number of tubes that meet EPRI criteria
    - o 50 tubes with single axial indications above top of tubesheet
    - o Tubes with axial cracks confined to within the tubesheet and above F* length
      - Conservatively evaluated on criteria for cracks emanating from the tubesheet

Farley -2 1990 Outage
Proposed Bases for Tube Plugging

OD SCC at TSPs

- o Continue to apply 1.75 volt criteria for tube plugging
  - Applied for DI resolution in last 2 outages at Farley -1 and 2
  - No leakage attributable to ODSCC at TSPs found at Farley-1 and 2
- o Negligible growth rates found for indications at TSBs
- o Supporting data indicates 1.75 volts is a conservative, no leakage criteria
  - Pulled tube, field experience and laboratory tests applied in EPRI program to develop plugging criteria for ODSCC at TSPs

Plugging Limits for PWSCC in Roll Transitions

Inspection Requirements

- 100% NDE over ~ ± 2" of top of tubesheet(1)
- Qualified NDE technique for PWSCC in RT
  - NDE qualified for detection of PWSCC in roll transitions by acceptable detectability threshold and demonstrated crack length measurement uncertainty
  - RPC applied for 1990 Farley-2 outage(1)

(1) Requirement consistent with EPRI Report

Plugging Limits for PWSCC in Roll Transitions

Definitions

- Axial Crack(1)
  - An axial crack network length with maximum inclination from the tube axis such that the circumferential projection is [ ]
- Roll Transition(1)
  - Tube axial region over which tube diameter changes from full expansion in the tubesheet to the nominal tube diameter
- F* Region(1)
  - The distance from the bottom of the roll transition to the F* length
- Crack Length Characterization(1)
  - Cracks emanating from top of tubesheet
  - Cracks initiating above top of tubesheet

(1) Definition consistent with EPRI Report.

Plugging Limits for PWSCC in Roll Transitions

Definitions (Cont'd.)

- Crack Growth Allowance - A_{CG} (1)
  - Allowance for average crack growth between inspections based upon growth of maximum to maximum crack lengths between inspections
  - Farley-2 1990 outage crack growth based on EPRI Report NP-6864-L
  - Crack growth at subsequent inspections to be based upon Farley-2 growth rates from 50 tubes left in service
- Crack length Measurement Uncertainty - A_{NDE} (1)
  - Demonstrated uncertainty on crack length measurement by NDE inspection technique based upon qualification of field NDE against actual crack lengths from pulled tubes
- Maximum Allowable Crack Length (1)
  - Maximum crack length that can be left in service but subject to constraint that predicted SLB leak rate is less than acceptance limit

(1) Definition consistent with EPRI Report.

Plugging Limits for PWSCC in Roll Transitions

Crack Length Limits(1)

- Cracks Emanating from Top of Tubesheet
  - Maximum Allowable: $A_1 = 0.52" - A_{CG} - A_{NDE}$
    $A_1 = 0.35"$
    - Includes tubesheet constraint effect on allowable length
- Axial Cracks Initiating Above Top of Tubesheet
  - Maximum Allowable: $A_2 = 0.35" - A_{CG} - A_{NDE}$
    $A_2 = 0.20"$
    - Does not include tubesheet constraint affect on allowable length
- Cracks Within F* Region
  - Conservatively grouped with axial cracks emanating from top of tubesheet

(1) Definition consistent with EPRI Report.

Plugging Limits for PWSCC in Roll Transitions

SLB Leak Rate Evaluation Requirements

- The predicted SLB leak rate based on the distribution of crack lengths left in service after each inspection shall not exceed 40 gpm per S/G

- Crack Lengths for leakage calculation

$$A_L = A_M + A_{CG} + A_{NDE}$$

A_M = measured crack length

- Method for Leak Rate Analysis

  - The method used to calculate leak rates shall be demonstrated to be approximately a plus 2-sigma confidence level relative to leak rate measurements on pulled tube roll transition cracks and laboratory induced axial cracks