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WCAP 13222

STEAM GENERATOR TUBE ALTERNATE PLUGGING CRITERIA PRESENTATION MATERIALS

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A meeting was held on February 6, 1992 in Rockville, Md. between Southern Nuclear Operating Company, Westinghouse and the NRR staff. An interim steam generator tube plugging criterion (1 cycle) for tube support plate elevation outer diameter stress corrosion cracking (OD SCC) for application at Farley Unit 2 was proposed at the meeting.

Westinghouse presentations at this meeting included discussions on:

1. Steam Line Break (SLB) Primary to Secondary Leakage Limit Radiological Analysis.

2. Steam Generator Pulled Tube Destructive Examinations.

3. Steam Generator Nondestructive Examinations (NDE) Topics and Considerations.

4. Probability of Tube Burst Under SLB.

5. SLB Leak Rate Versus Bobbin Probe Signal Amplitude Voltage.

A copy of the Westinghouse presentation material is provided herein.

STEAM LINE BREAK

PRIMARY TO SECONDARY LEAKAGE LIMIT

RADIOLOGICAL ANALYSIS

AGENDA

RADIOLOGICAL ANALYSIS ASSUMPTIONS

RESULTS

CONSERVATISM

RADIOLOGICAL ANALYSIS ASSUMPTIONS

* INITIAL PRIMARY COOLANT IODINE ACTIVITY

  1% FUEL DEFECTS
  (3.9 uCI/GM D.E. I-131)

* INITIAL SECONDARY COOLANT ACTIVITY

  0.1 uCI/GM D.E. I-131
  (TECH SPEC LIMIT)

* STEAM RELEASED TO THE ENVIRONMENT
  (0 TO 2 HOURS)

  2 SG'S IN INTACT LOOPS - 479,000 LBm

  SG IN RUPTURED LOOP - 91,000 LBm

* IODINE PARTITION COEFFICIENTS

INTACT LOOPS

STEAMING OF BULK WATER - 0.1
PRIMARY-TO-SECONDARY LEAKAGE - 1.0

LEAKAGE ASSUMED TO BE ABOVE MIXTURE LEVEL
NO MIXING OR PARTITION ASSUMED

RUPTURED LOOP

STEAMING OF BULK WATER - 1.0
PRIMARY-TO-SECONDARY LEAKAGE - 1.0

SG ASSUMED TO STEAM DRY - NO MIXING,
PARTITION OR RETENTION ASSUMED

* ATMOSPHERIC DISPERSION FACTOR
  7.6E-4 SEC/CU M

* THYROID DOSE CONVERSION FACTORS - ICRP 2

  1.48E6 REM/CURIE FOR I-131

* BREATHING RATE - 3.47E-4 CU M/SEC

  STANDARD SHORT-TERM RATE, R.G. 1.4

RESULTS

* OFFSITE DOSE ACCEPTANCE CRITERIA

  30 REM THYROID (2 HR SITE BOUNDARY)

  (SMALL FRACTION OF PART 100)

* CONTRIBUTION TO 2 HR THYROID DOSE

  INITIAL SG IODINE ACTIVITY - 2.4 REM

  P/S LEAKAGE - 0.5 REM/GAL/MIN

* ALLOWABLE LEAK RATES

  INTACT LOOPS - 0.2 GPM TOTAL
  (PROPOSED TECH SPEC LIMIT)

  RUPTURED LOOP - 55 GPM

CONSERVATISM WITH RESPECT TO FSAR ANALYSIS

THE FOLLOWING ARE THE CONSERVATISM OF THE ALLOWABLE LEAKAGE ANALYSIS (ALA):

1. RUPTURED LOOP P/S LEAKAGE

   ALA: DIRECT RELEASE TO ENVIRONMENT
   NO PARTITION OR RETENTION OF IODINE

   FSAR: RETENTION FACTOR OF 0.1

2. INTACT LOOP P/S LEAKAGE

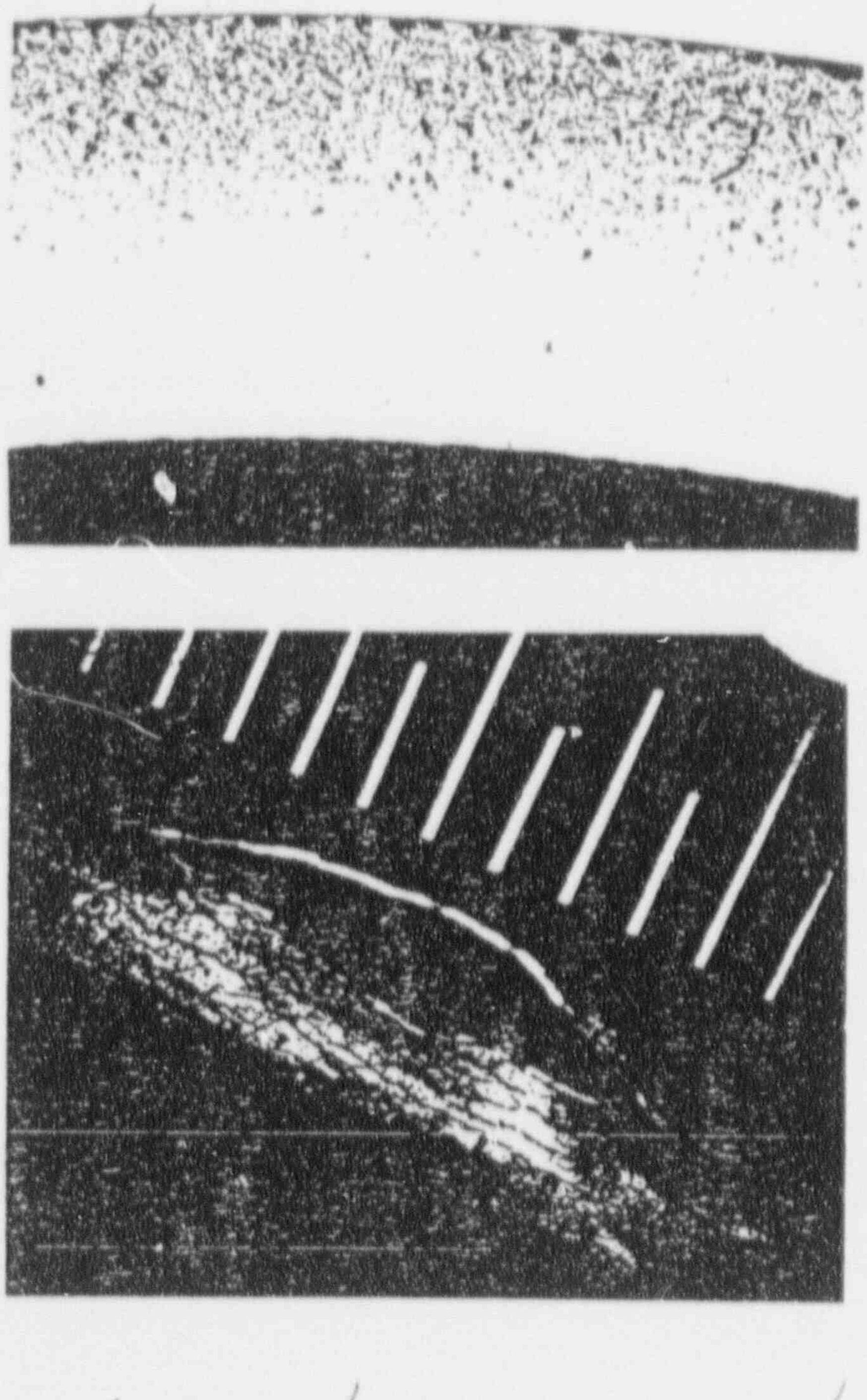
   ALA: LEAKAGE ABOVE MIXTURE LEVEL
   DIRECT RELEASE TO ENVIRONMENT
   NO PARTITION OR RETENTION OF IODINE

   FSAR: COMPLETE MIXING WITH SECONDARY COOLANT - PARTITION OF 0.1

3. DOSE ACCEPTANCE CRITERIA

ALA: 30 REM THYROID
(10 PERCENT OF 10 CFR 100 GUIDELINE)

FSAR: LESS THAN 10 CFR 100
ACTUAL DOSE LIMIT IS NOT SPECIFIED



(a)

(b)

FIGURE 2 Metallograph of IGA in a Sensitized 0.75 inch Diameter Tube and Burst Test Fracture Appearance

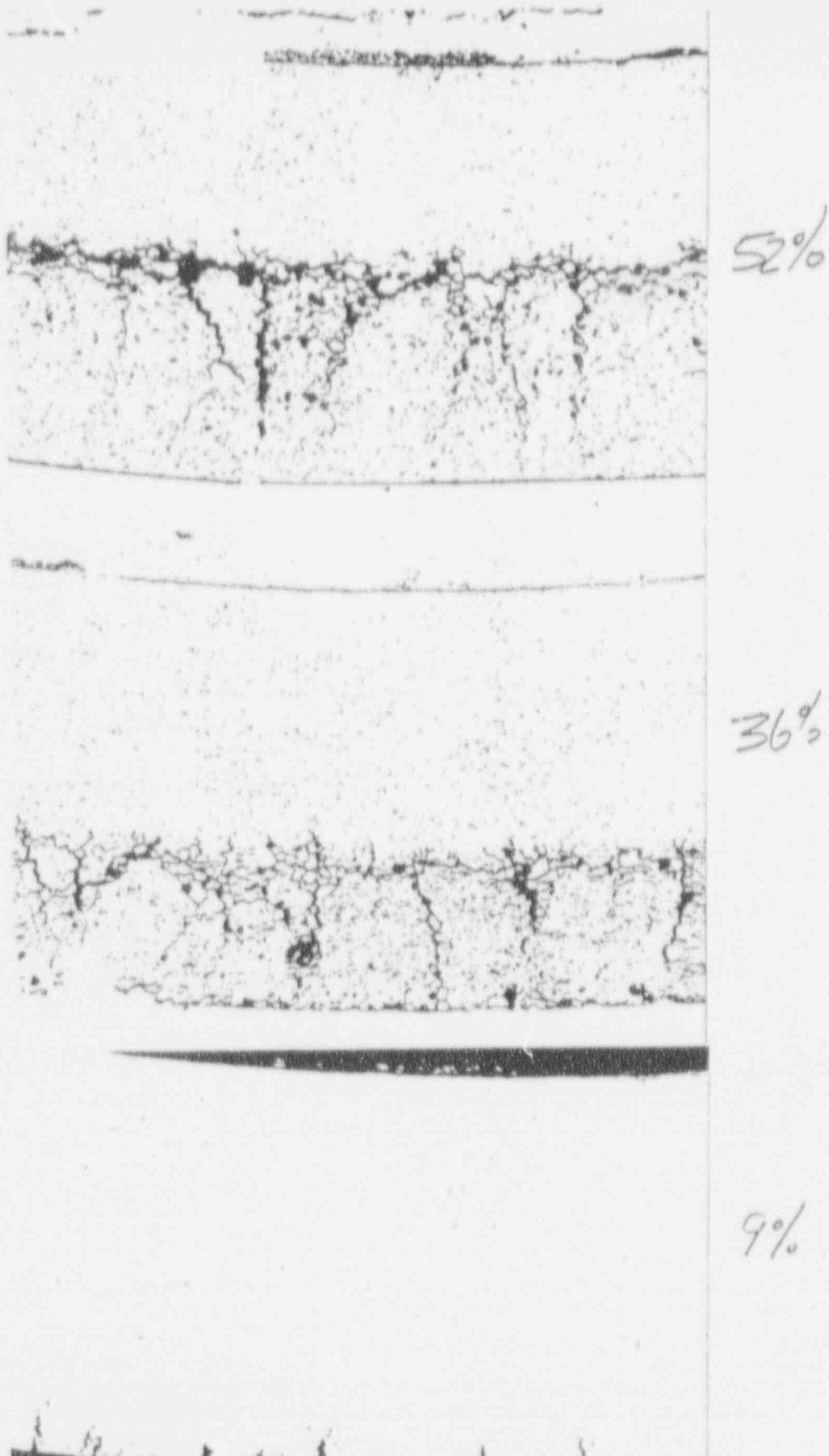


Figure 3 CRACKS IN IGA LAYERS CREATED DURING BURST TESTS.

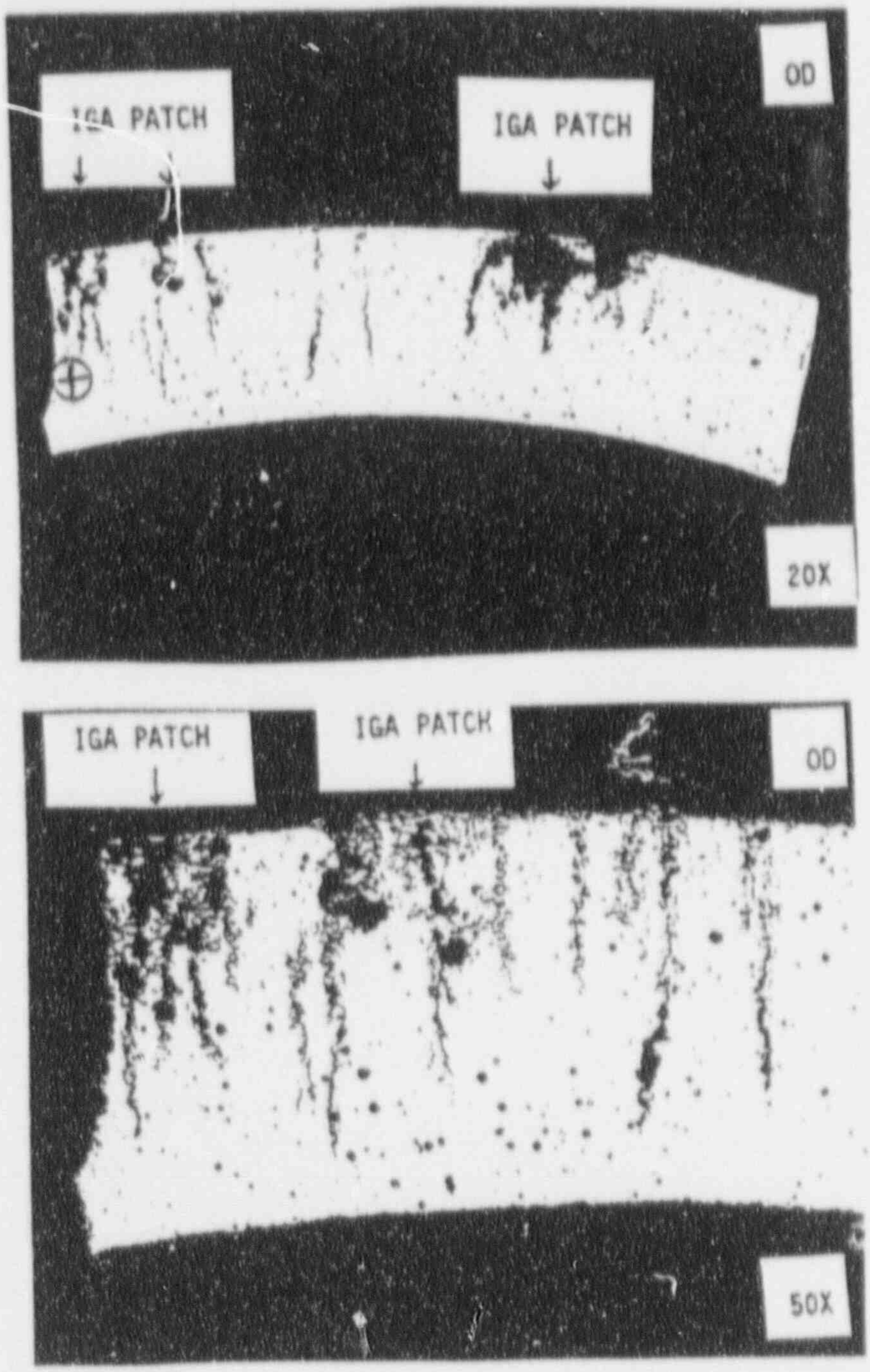
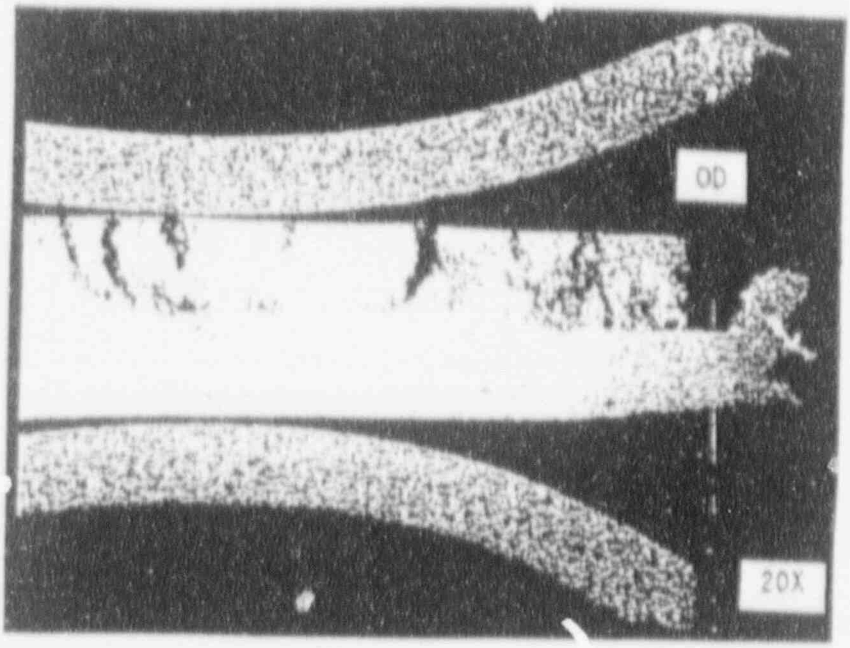


Figure 4-4 Transverse optical micrographs obtained just below the center of the support plate where the deepest corrosion was found at the 1st TSP of R12C8 (Tube plugged in 1989 and removed in 1991 and not representative of tubes left inservice). The deepest axial IGSCC is 85% through wall and three IGA patches are observed: one 43% through wall and 0.015 inch long, one 33% through wall and 0.05 inch long, and one 28% through wall and 0.015 inch long. The axial IGSCC had IGA aspects to individual cracks.



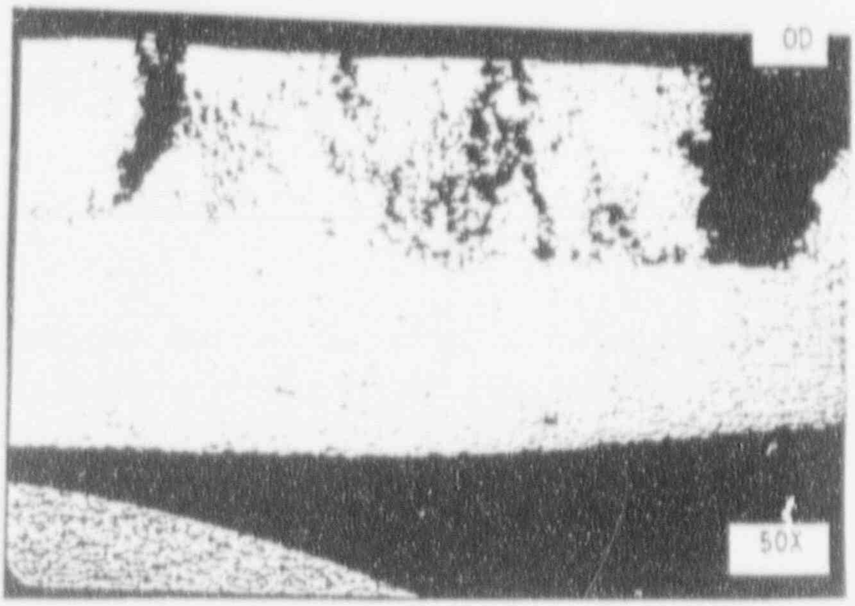


Figure 4-6 Axial optical micrographs obtained from the center of the support plate crevice region to the bottom edge of the crevice at a location where the deepest corrosion is believed to exist. A uniform corrosion front, approaching half way through wall, is observed within the crevice region. The section is believed to cut through a region composed of numerous axial microcracks.

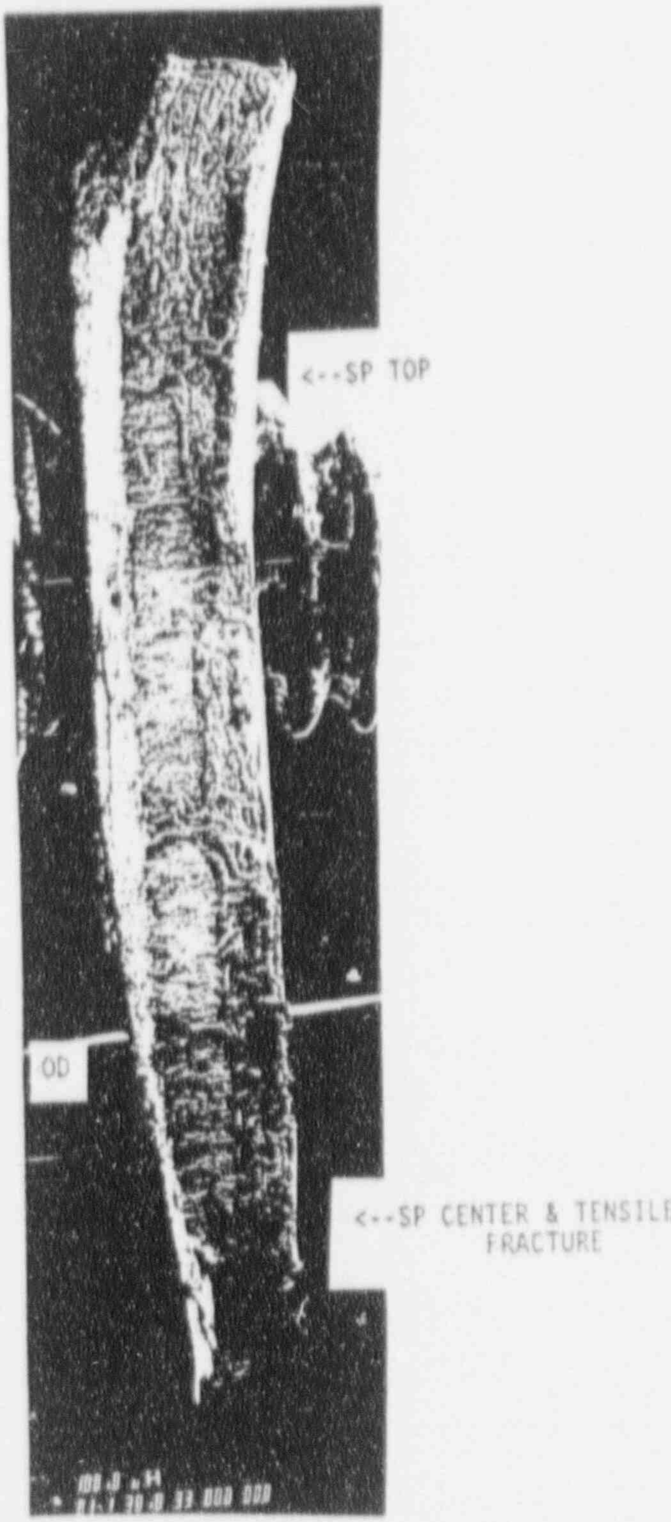


Figure 4-5 SEM photograph of axial fracture face from the first support plate center region to just above the top edge at a region believed to have the deepest corrosion. OD intergranular corrosion was observed continuously within the crevice region. Ledges were clearly observed separating individual microcracks. The depth of corrosion ranged from 41% through wall at the top edge of the crevice to 55% through wall 0.1 inch below the top edge of the crevice.

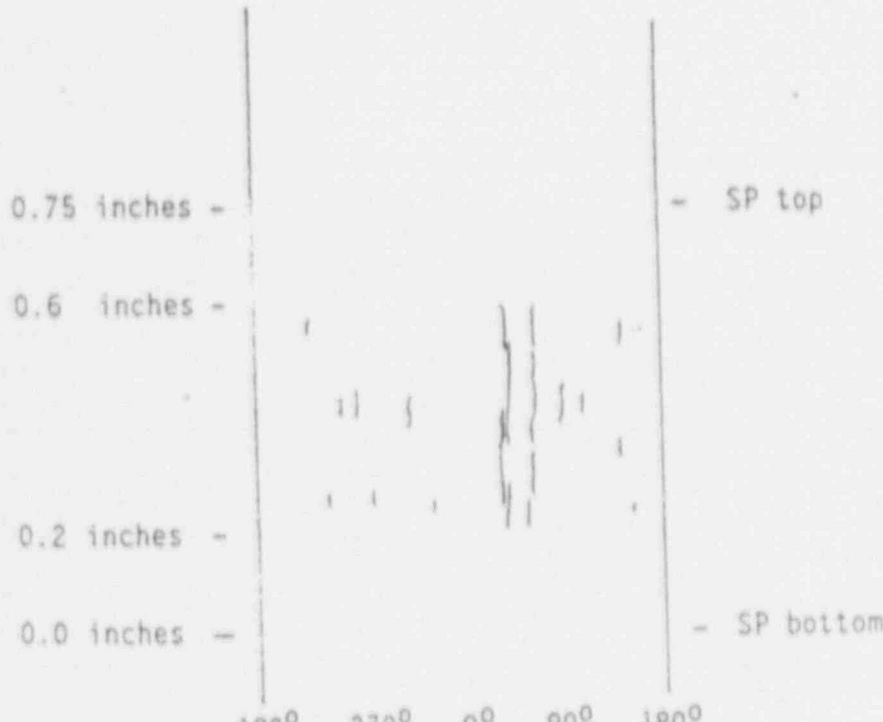
Sketch of Burst Crack

Macrocrack Length = 0.42 inches

Throughwall Length = 0.18 inches

Number of Microcracks = 4 (all ligaments with intergranular features)

Morphology = Intergranular SCC with some IGA characteristics (width of IGA 0.012 inches)



Sketch of Crack Distribution

Figure 4-4. Description of OD origin corrosion at the first support plate crevice region of Tube R4-C73.

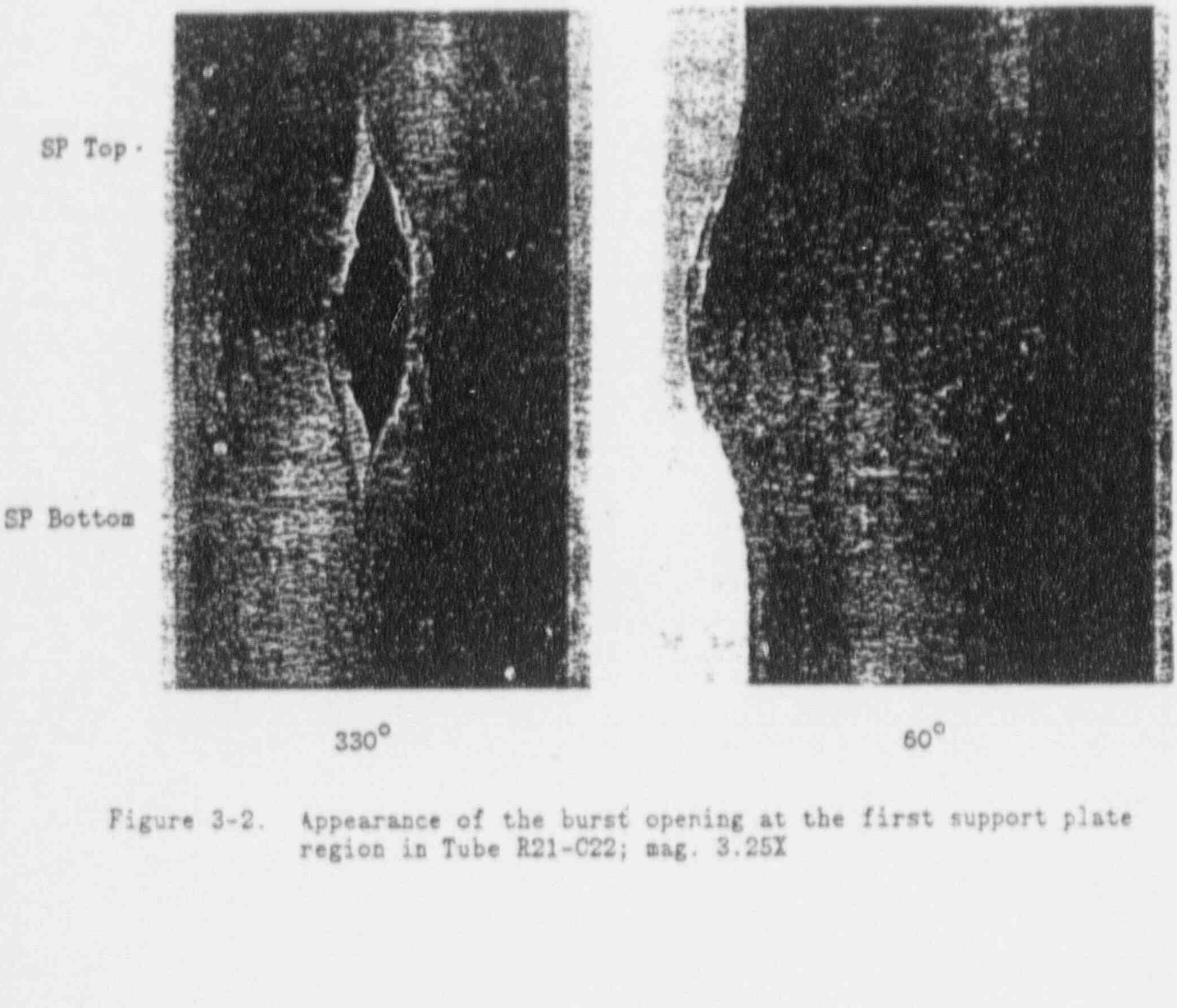


Figure 3-2. Appearance of the burst opening at the first support plate region in Tube R21-C22; mag. 3.25X

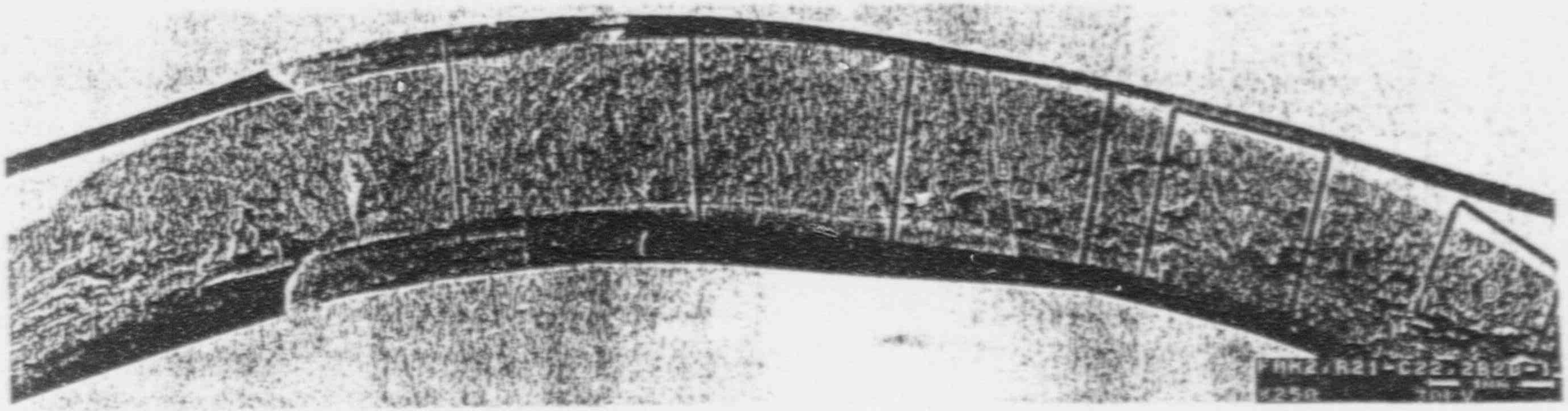
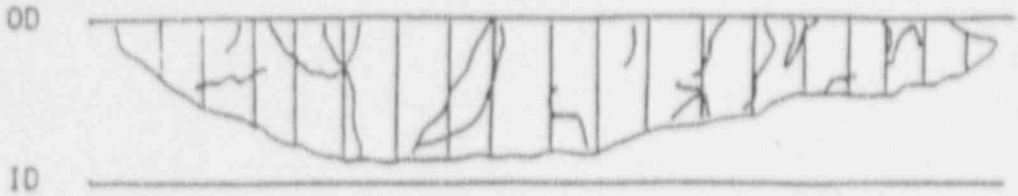


Figure 4-17. Fractographic features seen on the opened burst crack at 330°, at the first support plate intersection in Tube R21-C22. Areas marked were further examined in greater detail.



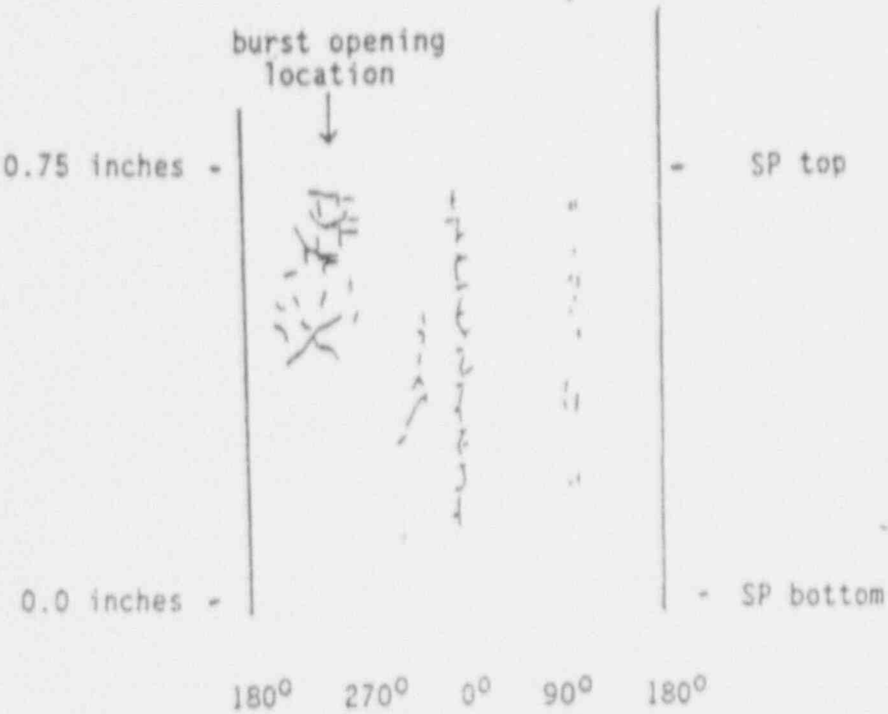
Sketch of Burst Crack

Macrocrack Length = 0.37 inches

Throughwall Length = 0 (78% throughwall)

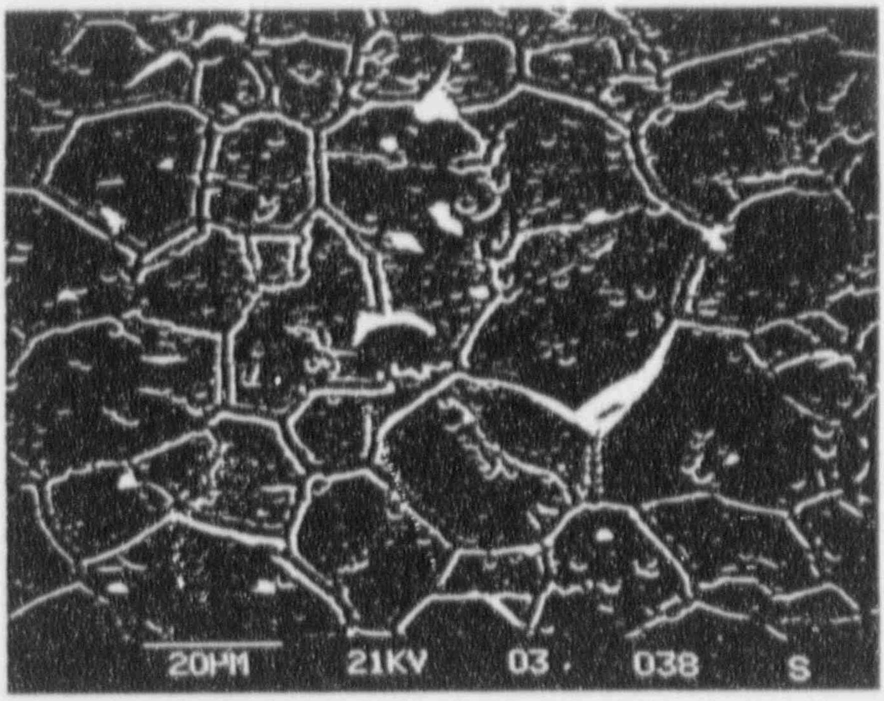
Number of Microcracks = numerous (ligaments have intergranular features)

Morphology = Intergranular SCC with minor IGA features (Unusual spider-shaped crack distribution)



Sketch of Crack Distribution

Figure 4-28. Description of OD origin corrosion at the first support plate crevice region of Tube R38-C46.



6400 HRS.
50% CAUSTIC
12% Cr_2O_3
700°F

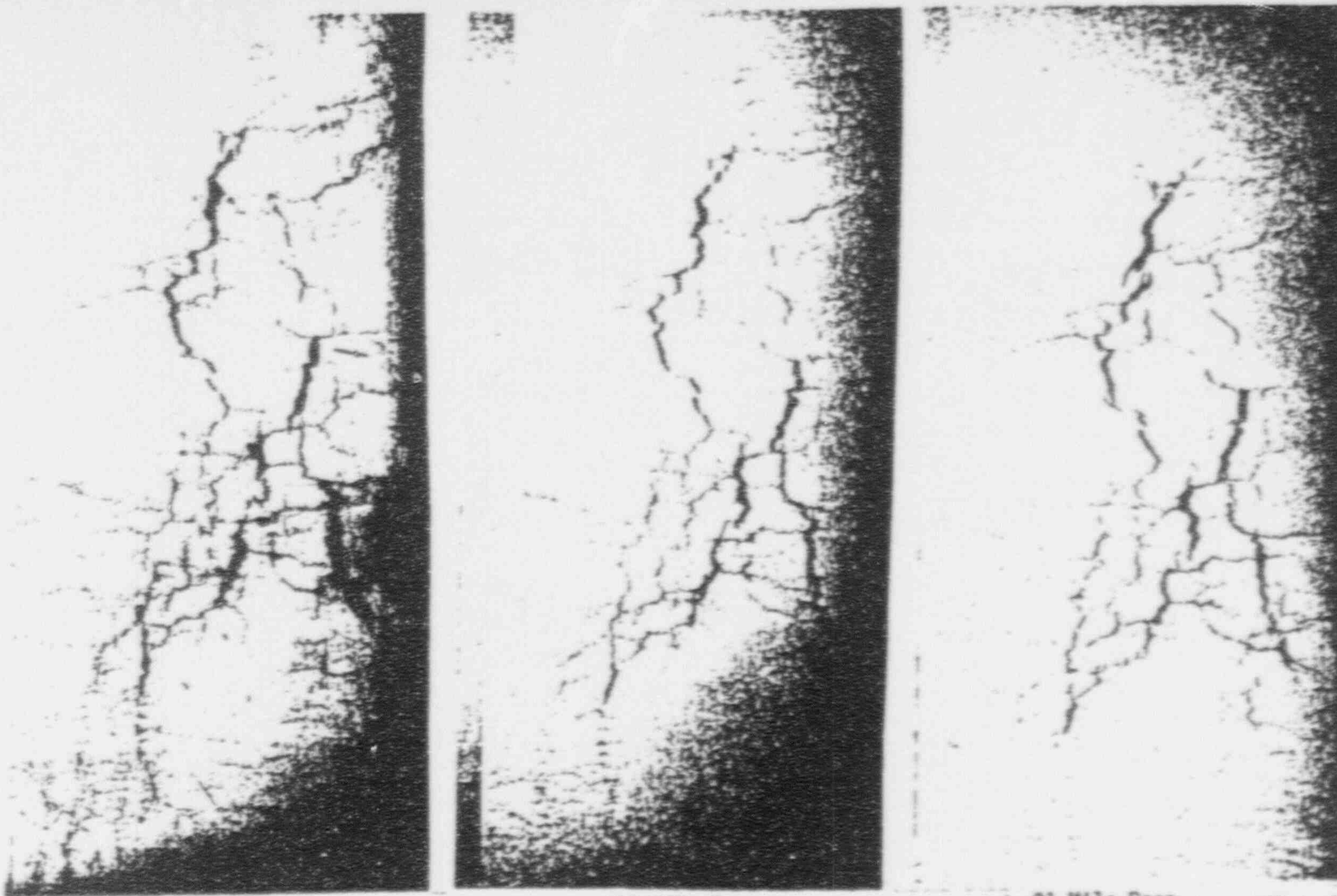


Figure 4-11 Photomicrographs of radial metallography performed on a region with axial and circumferential degradation on tube R16-C74, support plate 1. Cellular IGA was found with little change in the cell shape and cell wall thickness at depths of 4, 11 and 21 mils below the OD surface. Note that the cut section was flattened, preferentially opening the circumferential wall of the cells.

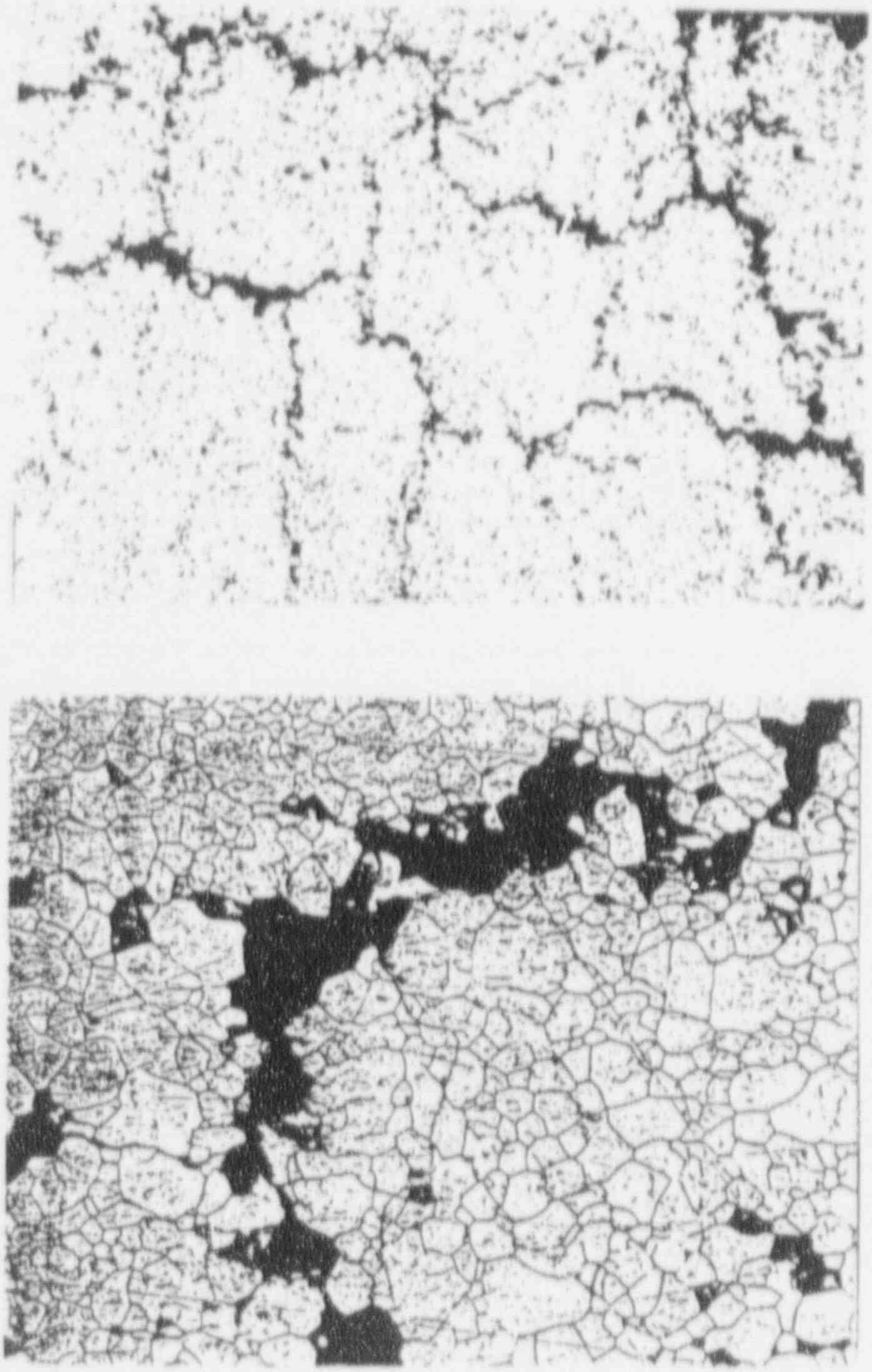
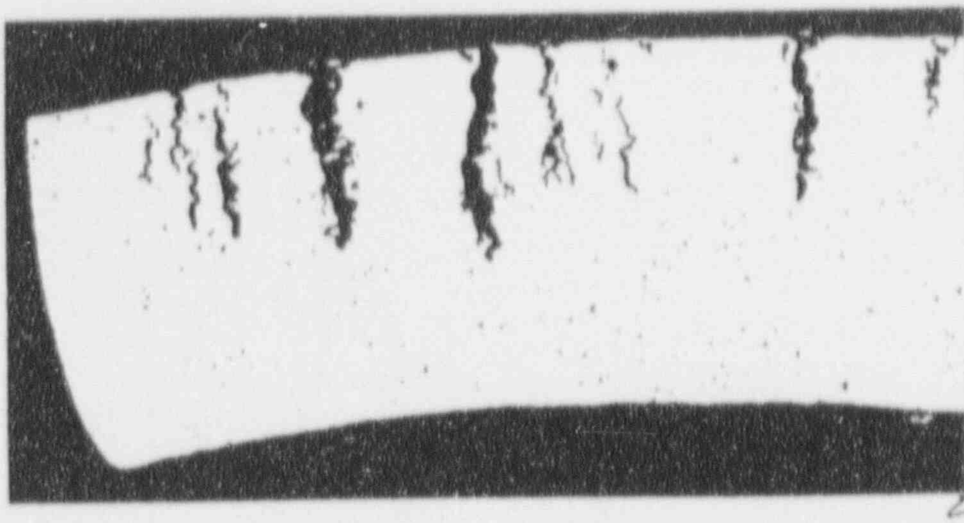


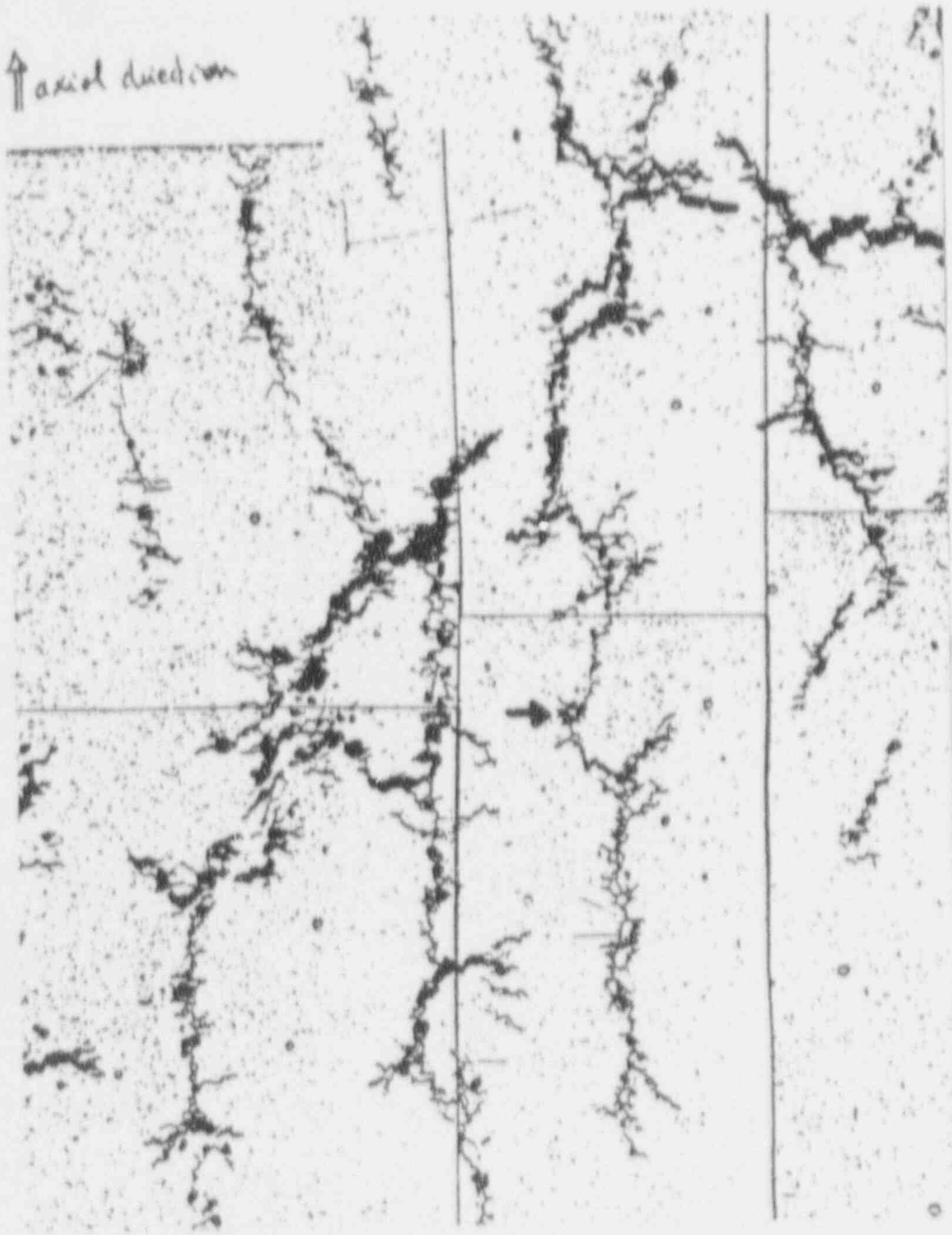
Figure 4-12 Higher magnification photomicrographs of the radial section shown in the previous figure. Top photo 50X, bottom 200X



TRANSVERSE CROSSECTION
R19C35
DOEL 4

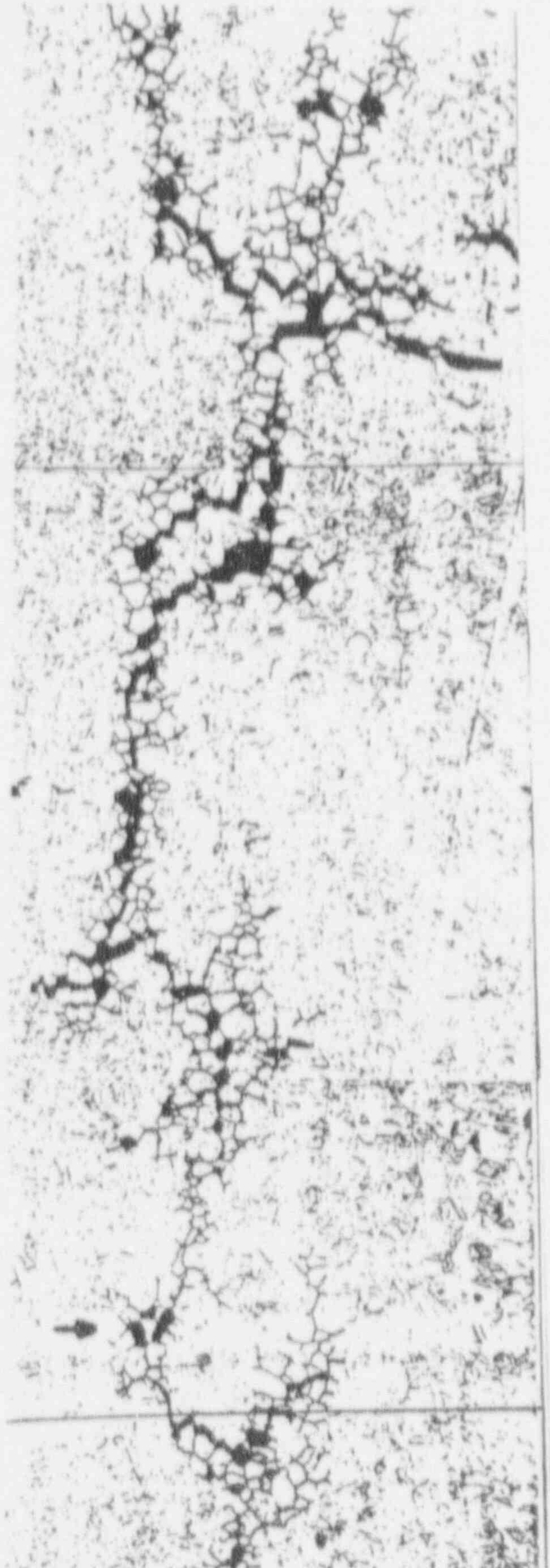
LONGITUDINAL SECTION

R19C35
DOEL-4



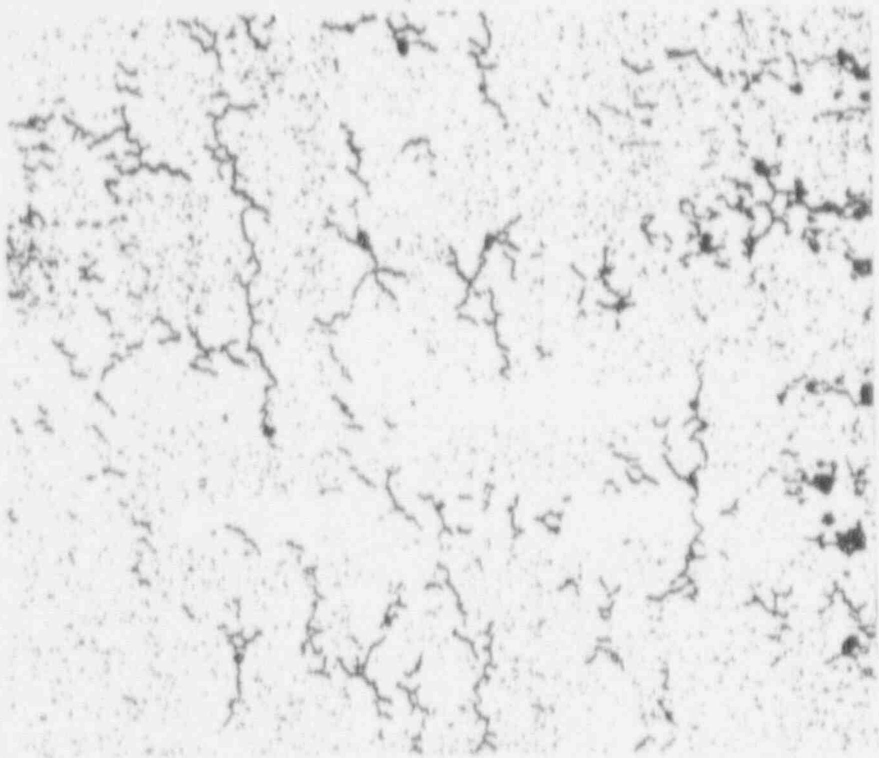
R19C35 50X

DOEL 4

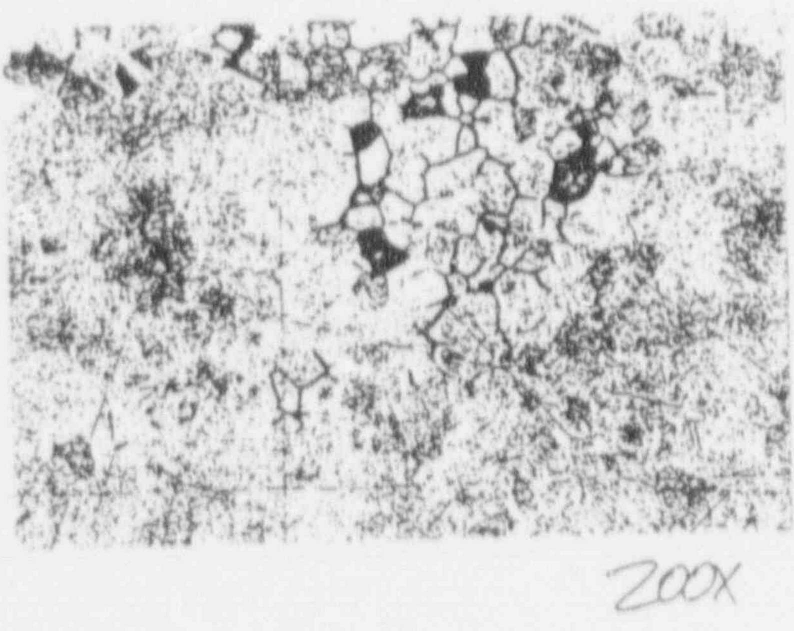


R19C35
DOEL 4

CRACKING/CELLULAR IGA



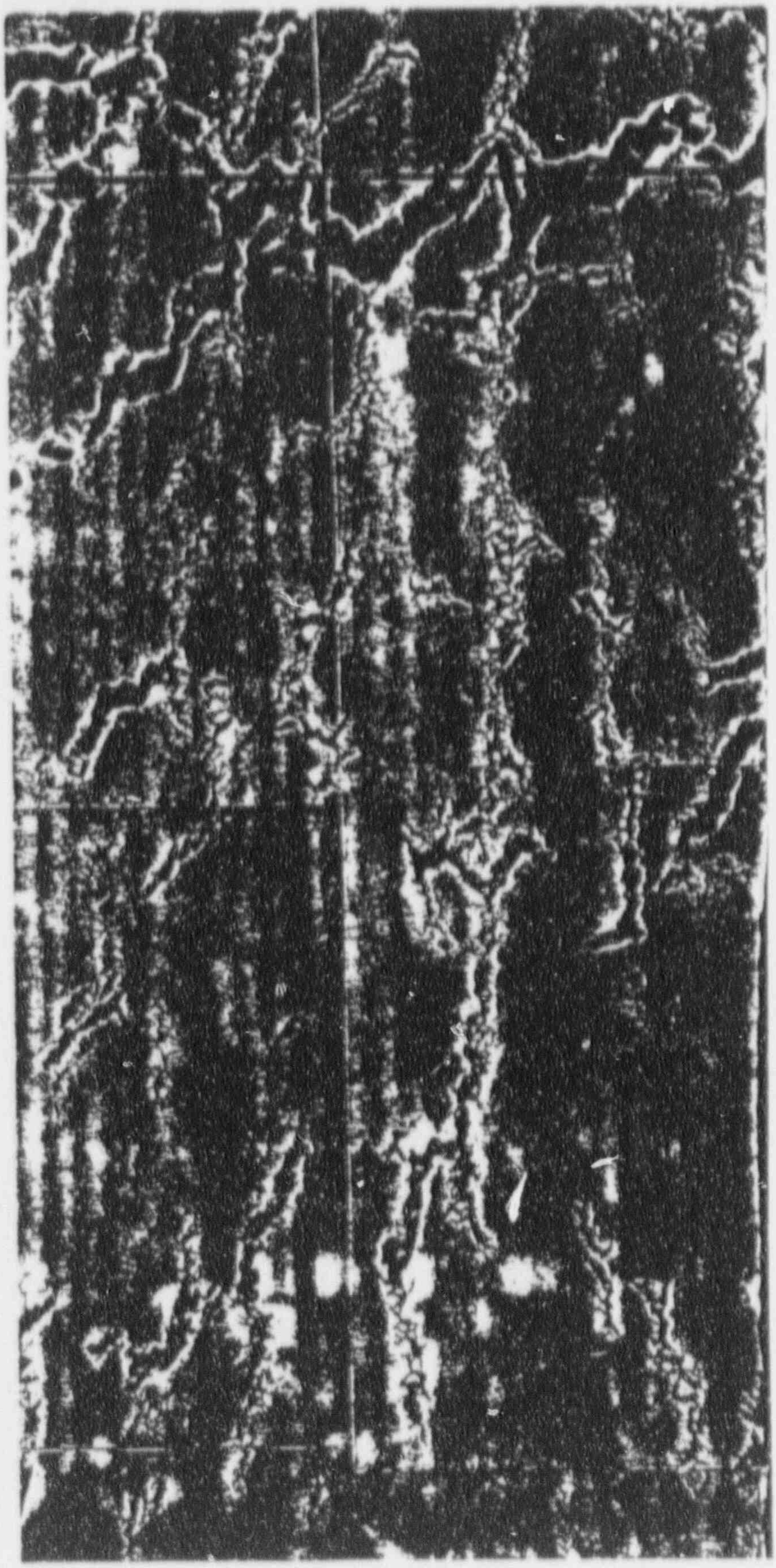
50X



SMALL PATCH OF VOLUMETRIC IGA

200X

R19 C35
DOEL 4



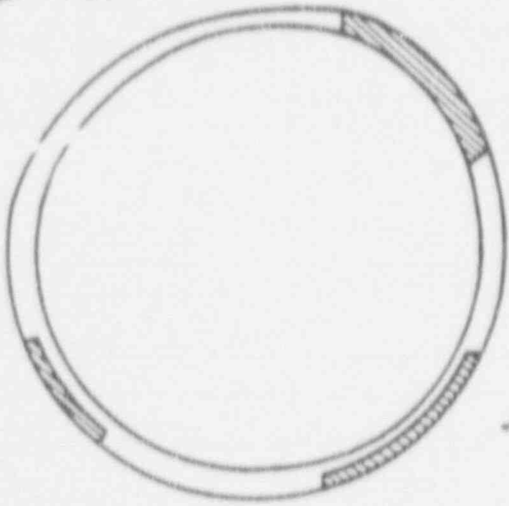
CHORD
SECTION

R42C4

DOEL - 4

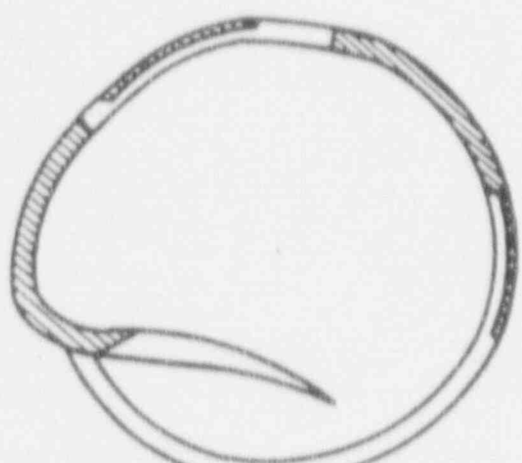
37X

TRANSVERSE CROSSECTION
SHADED AREAS INDICATE
INTERGRANULAR FRACTURE
APPEARANCE

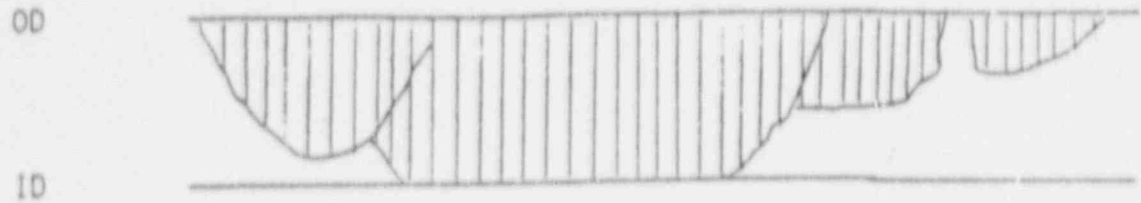


R42 C49
D72
F4

TUBES
FRACTURED
DURING
PULLING
OPERATION



R08 C47
A32
F3



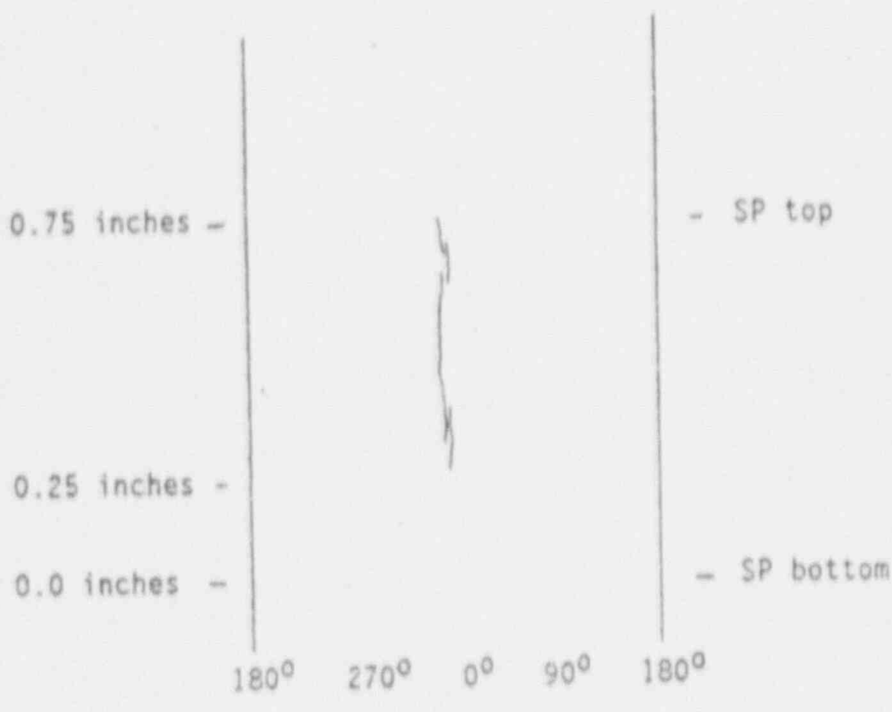
Sketch of Burst Crack

Macrocrack Length = 0.50 inches

Throughwall Length = 0.15 inches

Number of Microcracks = 4 (two ligaments with intergranular features, one with ductile overload features)

Morphology = Intergranular S.C with significant IGA characteristics (width of IGA 0.030 inches)



Sketch of Crack Distribution

Figure 4-21. Description of OD origin corrosion at the first support plate crevice region of Tube R21-C22.

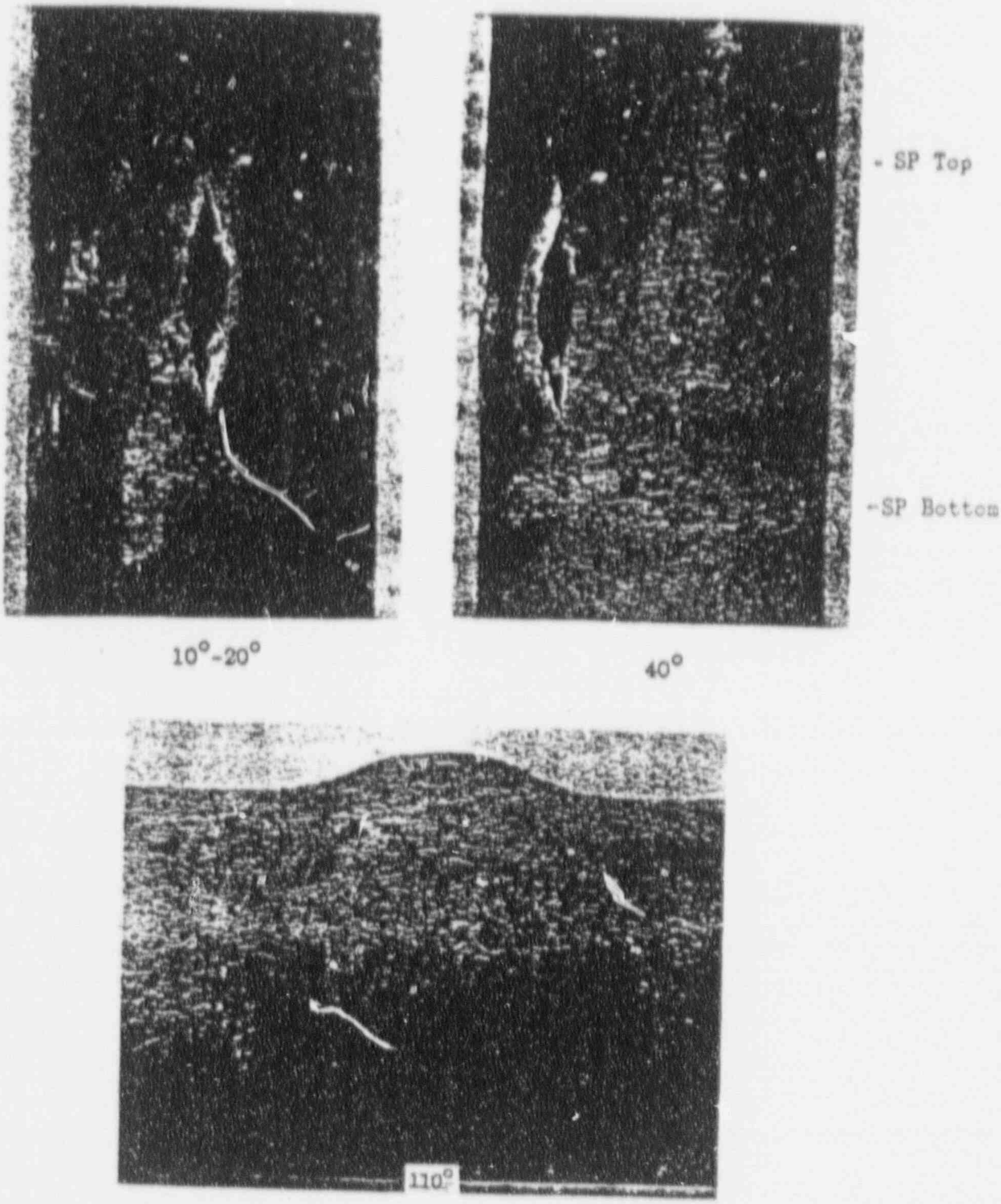


Figure 3-1. Appearance of the burst opening in Tube R4-C73 at the first support plate region; mag. 3.25X

Figure 10-6

TEST VS CALCULATED BURST PRESSURE

Farley

Steam Generator

NDE

Topics and Considerations

2-6-92

NDE Detectability for Belgian Indications

Doel-4 tube pull for TSP OD Intergranular Corrosion reported coexistence of 60% "IGA" and SCC.

Detectability of this condition prior to tube examination raised questions about adequacy of bobbin probes to respond to similar conditions within the parameters for the APC assumptions.

Differences between Belgian and U.S. approaches to identification of potential flaw signals center on relative calibration procedures.

> Belgian method establishes voltage response to 4-100% drilled holes at 2.0 volts using 300 kHz.
>
> Normalization to U.S. calibration gives 18.96 volts for 4-100% drilled holes using 400/100kHz TSP suppression mix.

Belgian detection scheme requires that signals exceed 0.2 volts (equivalent to ~2 volts on U.S. scale; this effectively filters out 95% of all TSP ODSCC calls made in U.S.

TABLE

Channel	U.S. - ASME Standard Signal Amplitude in Volts 20%	40%	60%	80%	100%	Support Plate	French Four 1 mm Diameter Holes 100%	Belgian Four 1.25 mm Diameter Holes 100%
Voltage Calibration Set According to U.S. Convention								
400/100 mix	2.75	2.8	5.3	5.6	8.7	<0.6	10.7	18.96
240 kHz	6.3	5.4	7.9	7.3	9.5	17.4	12.4*	21.15**
200 kHz	5.9	4.9	7.1	6.3	8.0	17.5	10.9	18.08
400 kHz	4	3.5	5.5	5.5	7.8	8.2	9.8	17.19
100 kHz	5.9	2.8	3.6	3.1	3.8	14.5	5.4	8.5
Voltage Calibration Set According to French Convention								
240 kHz	0.66	0.56	0.82	0.76	0.99	1.8	1.3*	
200 kHz	0.69	0.58	0.84	0.74	0.95	2.09	1.3	
400/100	0.33	0.34	0.64	0.67	1.04	-0.1	1.3	
Voltage Calibration According to Belgian Convention								
240 kHz	0.59	0.51	0.74	0.68	0.90	1.64		2.0**
200 kHz	0.62	0.53	0.76	0.67	0.85	1.87		2.0
400/100	0.29	0.29	0.55	0.59	0.91	-0.1		2.0
400	0.46	0.41	0.63	0.63	0.91	0.95		2.0

* At 240 kHz, the French 4-hole standard gives 12.4v when using our calibration procedures. It is 1.3 volt according to French calibration.

Thus U.S. values at 240 kHz/French values at 240 kHz ~9.5.
U.S. values at 400/100 mix/French values at 240 kHz ~8.2

** At 240 kHz the Beligian 4-hole standard gives 21.15 volt when using our calibration procedure. It is 2 volt according to Belgian calibration.

Thus, US values at 240 kHz/Belgian values at 240 kHz ~10.75
U.S. values at 400/100 mix/Belgian values at 240 kHz ~9.5

Belgian Tube Pull
Summary

All TSP intersection (excluding FDB) show cracking.

Affected areas are located entirely within the TSP intersections, mainly at mid-height.

Circumference affected is small at shallow depths, reaches almost 360 degrees in strongly affected intersections.

> Many initiation sites with multi-direction cracking for shallow attack.

Strongly-affected areas exhibit a dominance of axial cracking, with associated shallow IGA.

Burst cracks are axial in direction, showing 100% deep intergranular penetration.

Sections which broke upon pulling showed maximum 60% corrosion penetration, in a dense array of predominately axial cracks, with shallow IGA in some places.

Belgian NDE Practices

Examination of Belgian documentation for TSP ODSCC evaluation confirms that the reporting threshold for flaw signals is 0.2 volts.

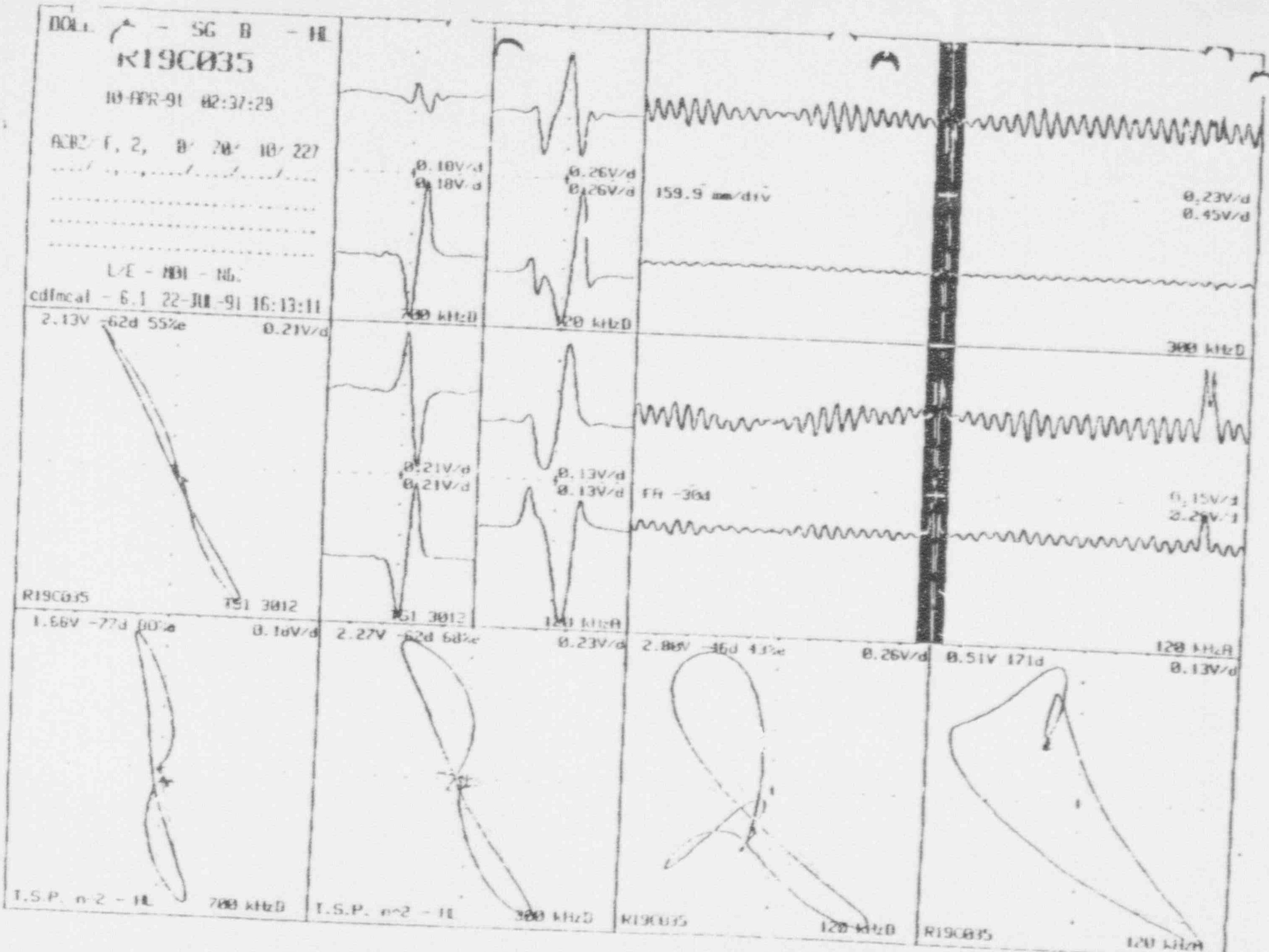
The computerized analysis system employed is capable of identifying signals smaller than 0.2v; these are mostly observed at 300 kHz and 120kHz.

Phase angle is measured at 700 kHz; this suppresses many of the OD signals since the EC field strength is optimized for only the deepest penetrations.

Amplitude is measured at 300 kHz, near the optimum detection frequency.

Doel-4 tubes are pilgered in manufacturing, leaving a large, periodic background noise over the entire tube length (See R19C35 - 2H data).

Flaws measured in the TSP suppression mix (300/120 kHz) do not appear appreciably different at 2.0 volts from their appearance (lissajous figures) in the 300 kHz and 700 kHz channels; this confirms that large amplitude signals - by U.S. standards - are being viewed.



DOL: - SG B - HL
R19C035
10-APR-91 02:37:29
ACBZ F, 2, 0 20 10 227
L/E - NBI - Nb.
cdlmcal - 6.1 22-JUL-91 16:13:11
2.13V -62d 55%e 0.21V/d
R19C035 TS1 3012
0.18V/d
0.18V/d
700 kHzD
0.21V/d
0.21V/d
TS1 3012
0.26V/d
0.26V/d
120 kHzD
0.13V/d
0.13V/d
120 kHzA
159.9 mm/div
FA -30d
0.23V/d
0.45V/d
300 kHzD
0.15V/d
2.2V/d
120 kHzA
1.66V -77d 80%e 0.18V/d
T.S.P. n-2 - HL 700 kHzD
2.27V -62d 68%e 0.23V/d
T.S.P. n-2 - HL 300 kHzD
2.80V -36d 43%e 0.26V/d
R19C035 120 kHzD
0.51V 171d 0.13V/d
R19C035 120 kHzA

IGA Detection - Historical

- IGA was first noted by tube pull in the tubesheet crevice of Point Beach tubes.
  - Deep IGA was found in the entire tubesheet crevice

- It was not reported in the field by E.C. inspection.
  - A review of the 100 kHz absolute data produce "drift" indicative of IGA along the entire tubesheet crevice.

- At San Onofre IGA detection at the top of the tubesheet was complicated because of presence of dent at the top of tubesheet.
  - Nevertheless ~400 tubes with IGA and/or circumferential cracking were detected by the initial bobbin examination.

- Detection of IGA in the tubesheet crevices at Ginna plant is routinely performed using the absolute bobbin mode.

DDM0841:020492

IGA Detectability

- Field and Lab. experience shows that the threshold of detectability of volumetric IGA in the support plate intersection using bobbin probe is in the range of 20% depth.

  Examples:

  Point Beach ~~#1~~ 2 - detected at ~25% depth
  St. Lucie #1 - detected at ~15% depth

- The 400/100 diff. mix channel was used for this detection although 400 kHz differential channel alone was enough for the case of St. Lucie #1 which has egg crate supports.

- In cases where both SCC and volumetric IGA are present, SCC is often found to extend beyond the IGA--and the SCC signal may dominate.

Pulled Tubes With IGA

Plant	Tube Number	Location	400/100 Mix (Diff.)	Destructive Examination	Remarks
Point Beach #2 (1987)	R29C46	1C	1.8V/26%	26%	Volumetric IGA 360° around 3/4" long section
St. Lucie #1 1985	L59R95	1H (Crate)	0.4V/66%	52% Max. Depth 20% IGA Depth	Volumetric IGA with figures/SCC 0.3" 0.7" 
		2H (Crate)	0.6V/29%	13%	Volumetric IGA <0.3" 0.7" 

Lab IGA Samples

Mill Annealed Tubes	400/100 (abs) mix		
	4.5 volt	20%	Uniform IGA 360° around the 4" long section
	9 volt	40%	Uniform IGA 360° around the 4" long section

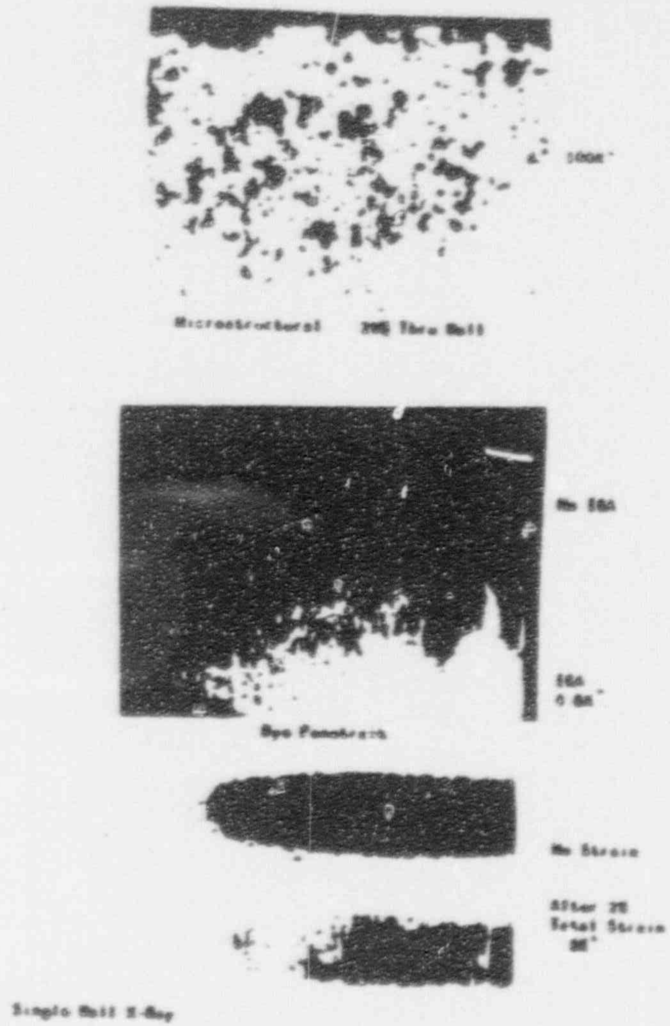


Figure 8- 13a. NDE Results for a Type 1 (IGA) Sample (Dye Penetrant and X-Ray)

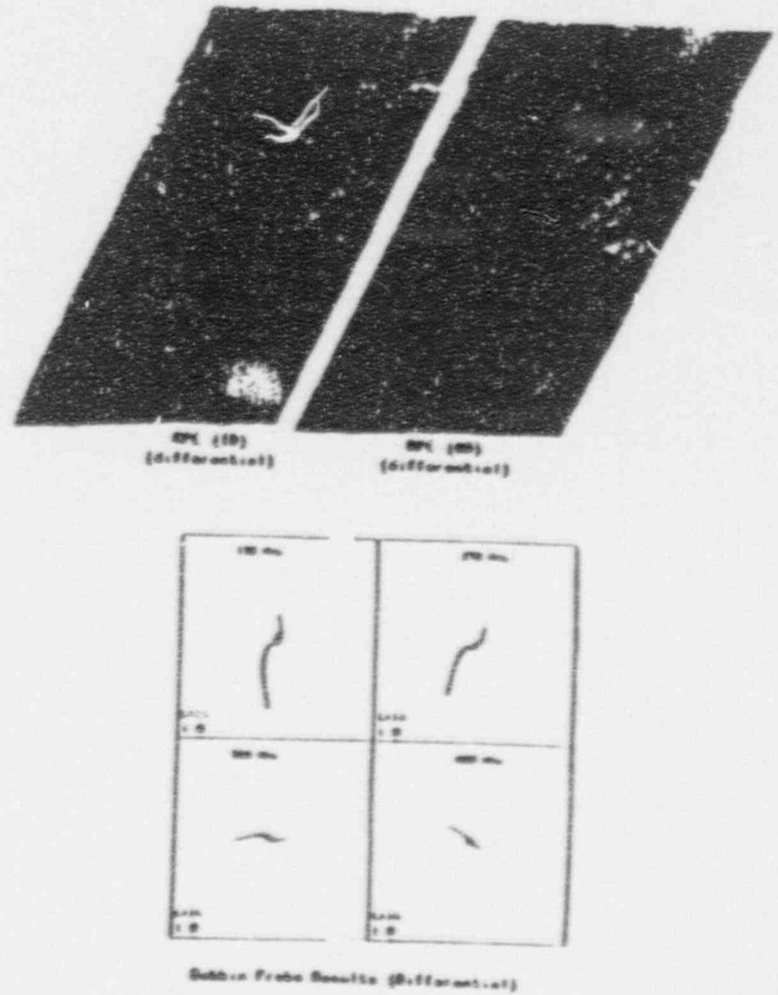


Figure 8- 13b. NDE REsults for Type 1 (IGA) Damage (Eddy Current)

Figure 8- 13. Inspection Results for Laboratory IGA Samples from EPRI Program

Figure 8-12a

Bobbin Data and Typical Metallographic Sections of Simulated IGA Specimens Using Sensitized Alloy 600MA Tubing

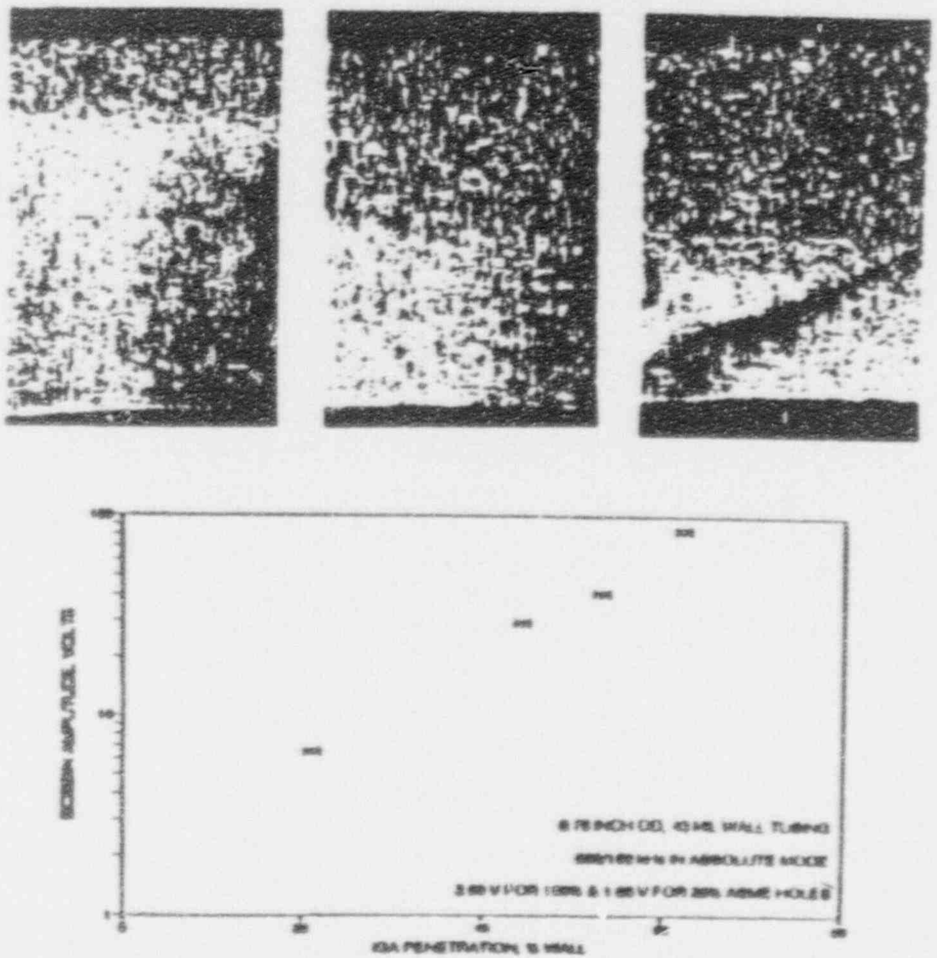


Figure 8-12b

Bobbin Data from Simulated IGA Specimens Using Non-Sensitized Alloy 600MA Tubing

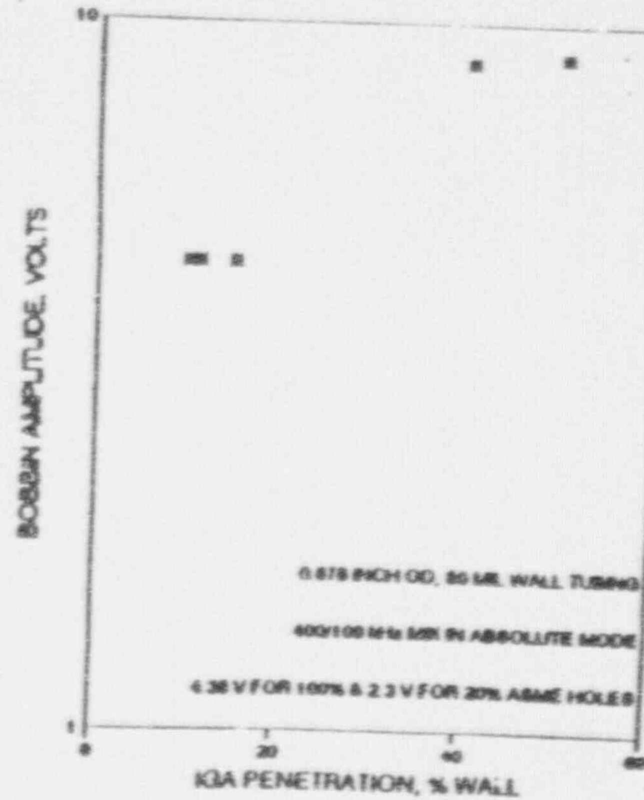


Figure 8-12. Bobbin Coil Results for Laboratory IGA Specimens

Influence of Denting on Detection of TSP ODSCC

Severe tube deformation typical of denting observed at Surry and Turkey Point plants in the 1975-82 period effectively masks tube degradation from bobbin coil detection.

> Extensive denting included 100% of TSP intersections affected, tube I.D. restrictions, TSP ligament failure/hourglassing of flow slots, and repeated tube leakage incidents.

Farley-1 steam generators exhibit approximately <1% of TSP elevations with dents, with typical voltage ~3 volts, measured peak-to-peak. Farley-2 steam generators exhibit only random dents attendant to handling and assembly processes.

Detection of ODSCC signals ~1.5 volts in the presence of dents is up to 10 volts peak-to-peak is expected to be straightforward with bobbin probes.

Vector Combination of Flaw and Dent Signals

Vector combination of flaw signals of 1.5 volts with 5 volt (one lobe of 10v peak-to-peak signal) dents in the range of 40° (100% TWD) to 110° (40% TWD) will produce resultant signals with a phase angle of approximately 165°.

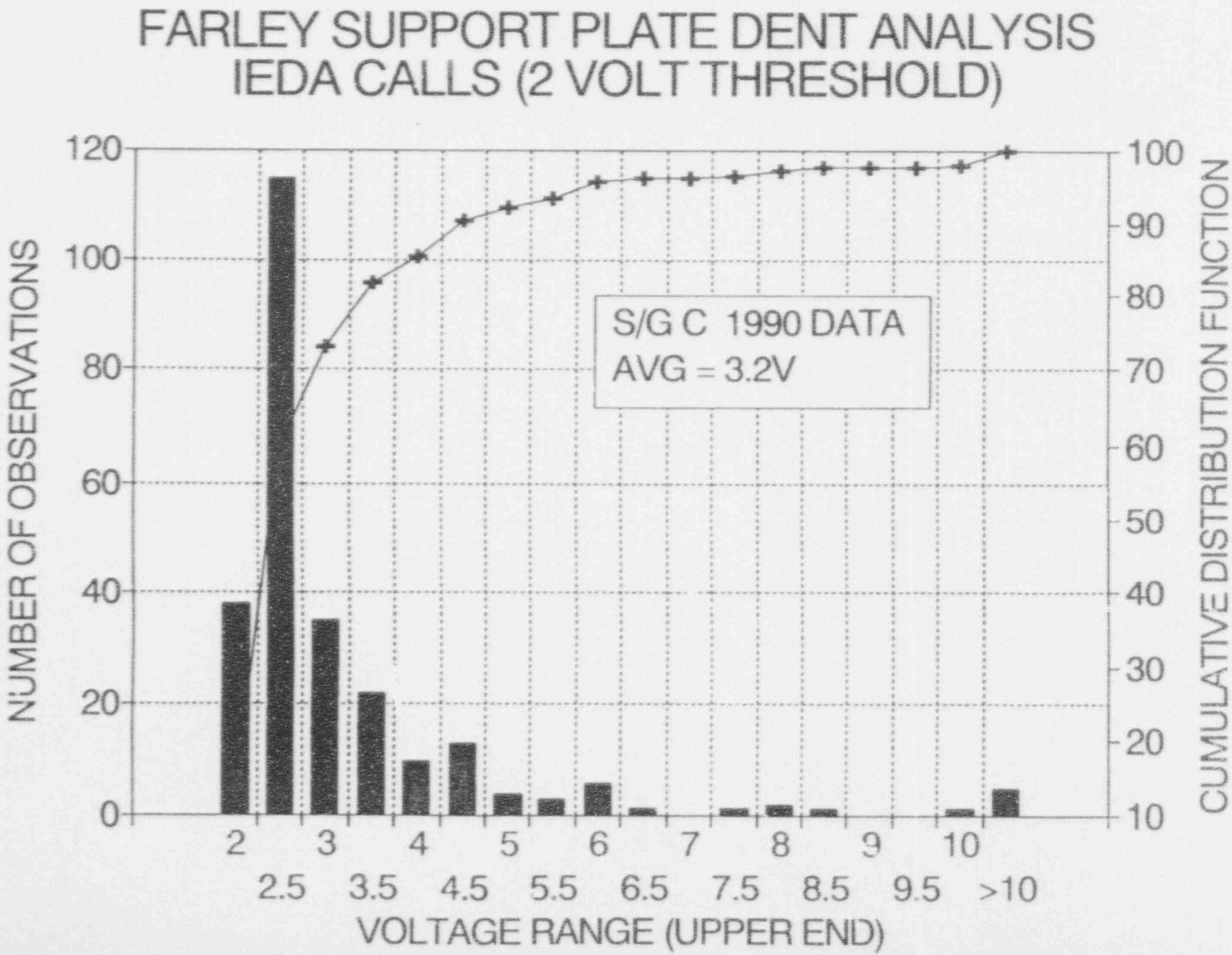
All such signals fall within the Farley guidelines flaw reporting phase angle window - >0° to <180°.

Allowance must be made for phase angle variation of dent/probe motion.

> If observed signal phase angle lies within 10° of 180°, larger amplitude dents will be indistinguishable from combined flaw with dent resultants.

Farley EC interpretation guidelines will identify TSP signals in the 10°-170° range for RPC testing if they exceed 1.5 volts; dent signals exceeding 13 volts peak-to-peak will be sampled with RPC to verify the absence of circumferential cracks.

DDM0841:020492


FARLEY SUPPORT PLATE DENT ANALYSIS
IEDA CALLS (2 VOLT THRESHOLD)
NUMBER OF OBSERVATIONS
0
20
40
60
80
100
120
CUMULATIVE DISTRIBUTION FUNCTION
10
20
30
40
50
60
70
80
90
100
S/G C 1990 DATA
AVG = 3.2V
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
>10
VOLTAGE RANGE (UPPER END)

Calibration
and
Probe Centering Uncertainty

The 4-hole staggered standard is used to obtain average bobbin signal amplitude at the beginning of a probe's use.

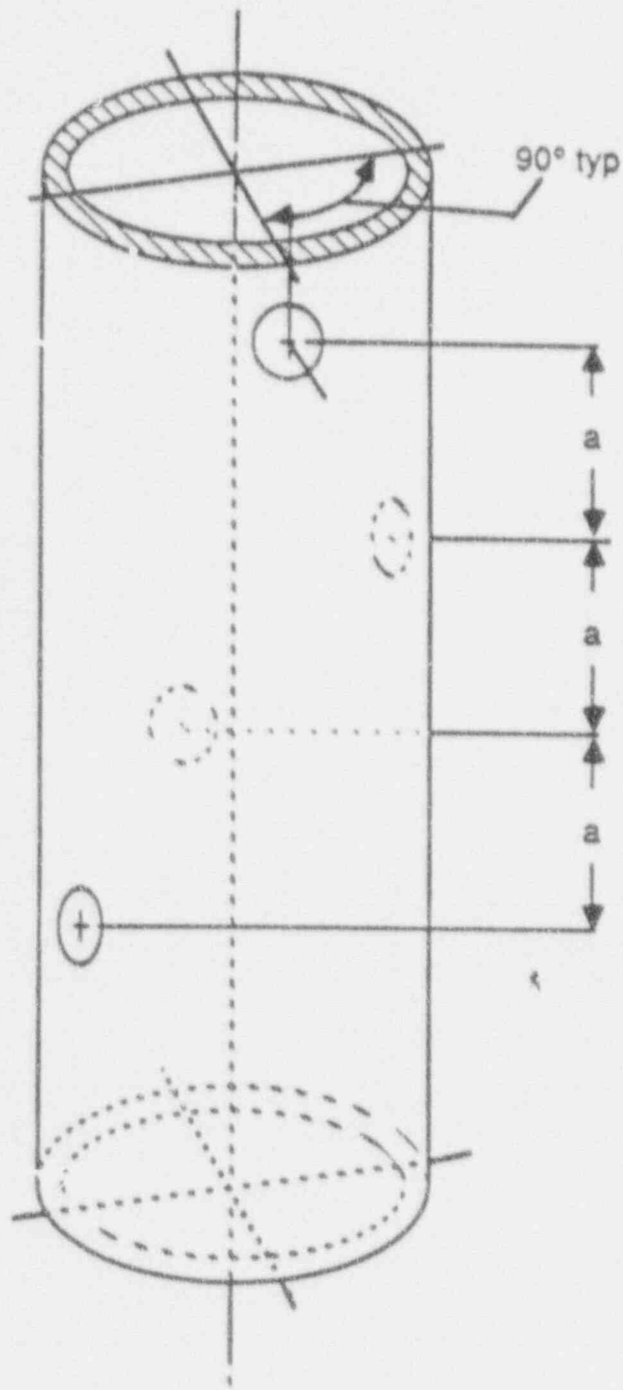
The uncertainty induced by probe wear is monitored by periodic insertions of the probe into the standard.

Comparison of these readings will permit determination of unacceptable centering (excessive wear). It is not necessary to control the response of individual probes to a constant initial value.

Manufacturing tolerances may be disregarded so long as the probes' responses are referred to the same standard for their useful life.

Figure 8-18

Probe Wear Calibration Standard



TSP ODSCC

Detection of Growth Outside the TSP

Cracks extending beyond the TSP are detected with the same probability and accuracy associated with free span tubing.

For cracks still influenced by the TSP signal uncertainty associated with the covered (TSP) span is expected.

To the extent that edge effects compromise detection of cracks, no more than 0.2" axial length outside the TSP is affected.

Signals with low voltage only. See Table 8.1 for influence of flaw location on bobbin coil measurements. (WCAP-12871, Rev. 1)

Table 8.1

Effect of Flaw Location on Bobbin Coil Measurements*

Flaw Location	50% Deep Slot Voltage	50% Deep Slot Depth	100% Deep Slot Voltage	100% Deep Slot Depth
1. Slot centered in TSP	0.95	43%	47.4	100%
2. Slot extending from TSP edge inside TSP	0.95	72%	48.1	100%
3. Slot extending from TSP edge outside of TSP	1.07	36%	49.3	99%
4. Slot without a TSP	1.07	49%	48.7	99%

* Measurements for 0.25 inch long EDM slot in 0.75 inch diameter tubing.

Eddy Current Reliability

The detection of axial ODSCC at TSP's with bobbin coil has been shown to have 100% detection probability for flaws in excess of 40% TWD.

> ANALYST INTERPRETATION GUIDELINES HAVE CLOUDED THE CERTAINTY OF THIS FACT, SO THAT INSPECTION SYSTEMS INCLUDING DETECTOR, DELIVERY SYSTEM, ANALYSIS RULES AND ANALYST MAY PRODUCE PERFORMANCE WHICH FALLS SHORT OF THE PROBE CAPABILITY.

Significant flaws in the axial ODSCC category may be defined as single 100% TWD cracks or arrays of aligned 100% TWD microcracks whose composite length and amplitude as measured combined with anticipated growth and due allowance for measurement error would not withstand pressure transients to 3ΔP for normal operation or to the Steam Line Break ΔP, i.e. would exceed the critical crack length.

> For 7/8" 0.050" Alloy 600 tubing the critical crack length for Farley steam generator tubing is 0.84" for SLB and 0.42" for 3ΔP.

DETECTION OF SIGNIFICANT FLAWS

BOBBIN RESPONSE TO SIGNIFICANT FLAWS, I.E. THOSE WITH THROUGHWALL (100% TWD) DEPTH OF LENGTH APPROACHING CRITICAL LENGTHS:

> IN THE ABSENCE OF MAJOR INTERFERENCES, FOR CRACKS WITH SIGNIFICANT LENGTH (>0.02") 100% TWD, BOBBIN AMPLITUDES GREATER THAN 1.5 VOLTS ARE EXPECTED.

FLAW IDENTIFICATION OF SIGNALS WITH AMPLITUDES >0.5 VOLTS IS ROUTINELY ACHIEVED, AND FLAW SIGNAL AMPLITUDES ≥ 1.5 VOLTS ARE DETECTABLE WITH NEAR 100% CERTAINTY UNDER FARLEY GUIDELINES EVEN WITH DENTS UP TO 13 VOLTS PEAK-TO-PEAK.

Detection of Critical Length Flaws

Bobbin amplitudes corresponding to significant flaws are bounded by slot length vs bobbin voltage data

Fig. 8.2 WCAP-12871, Rev. 1

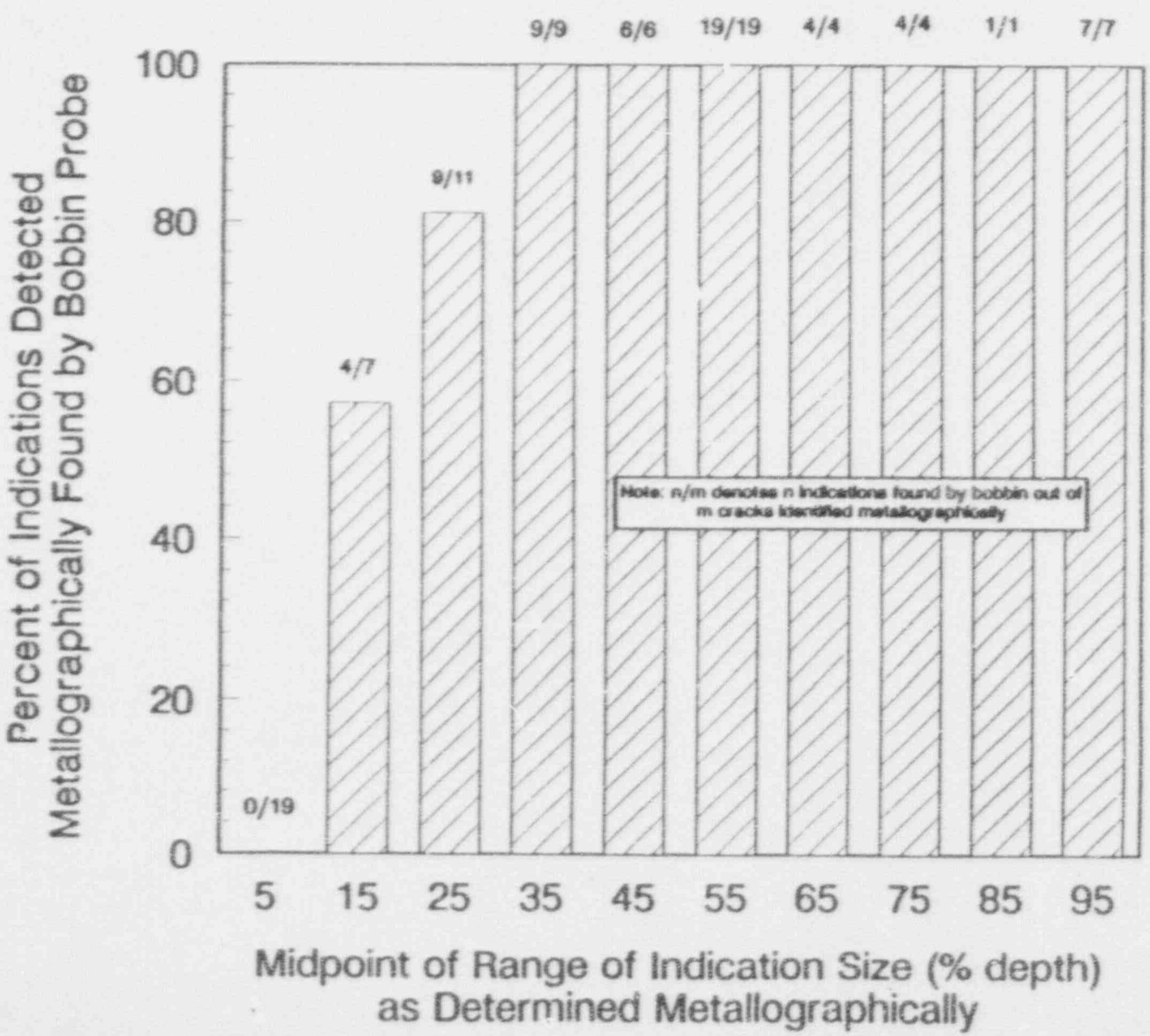
Amplitude of 0.4" rectangular slot 0.006" wide at 400/100 kHz ~70 volts at 100% TWD.

ODSCC resulting from single crack 100% TWD will be lower, since effective width - hence volume - is smaller.

Sample		Bobbin Amplitude	% TW Length
MB#576-4		8.4 volts	0.43"
#555-3		22.6 volts	0.42"
#558-1		6.5 volts	0.32"
#571-1		10.7 volts	0.35"
Farley 2	R4C73	2.6-5.0 volts	0.18"
	R21C22	7.7-14.2 volts	0.15"
	R38C46	1.4 volts	0.00
	R31C46	7.2 volts	0.02"

Through-wall cracks dominate the EC bobbin response generated by tubing with several parallel cracks.

Detection Probabilities



6) PROBABILITY OF TUBE BURST UNDER SLB

- o USE MONTE CARLO TECHNIQUES TO ESTABLISH EOC SLB PROBABILITY OF TUBE BURST FOR EACH STEAM GENERATOR

  - ACCOUNTING FOR THE VOLTAGE GROWTH RATE, THE EDDY CURRENT UNCERTAINTY AND THE REVISED BURST PRESSURE VS VOLTAGE CORRELATION, THE FARLEY 2 VOLTAGE DISTRIBUTIONS OF 1990 WOULD HAVE A PROBABILITY OF 1×10^{-3} OF HAVING BURST CAPABILITY < 2650 PSI (SLB)

- o COMPARE TO THE LEVEL GIVEN IN NUREG-0844. A SINGLE TUBE RUPTURE EVENT SHOULD HAVE A PROBABILITY OF $< 2.5 \times 10^{-2}$.

  - THE CALCULATED PROBABILITY, 1×10^{-3}, IS $< 2.5 \times 10^{-2}$

oCONCERN/SUGGESTION
-RESPONSE

Calculation of Burst Pressure

a,c

a, c

[ ] a, c

FARLEY 89-90 TSP/ALTERNATE PLUGGING CRITERIA BURST PRESSURE 7/8 SG A

MINIMUM BURST PRESSURE	PROBABILITY [a]
3.1	
3.7	
4.0	
4.2	
4.4	
4.5	
4.8	
4.9	
5.0	
5.1	
5.2	
5.3	
5.4	
5.5	
5.6	
5.7	
5.8	
5.9	
6.0	
6.1	
6.2	
6.3	
6.4	
6.5	
6.6	
6.7	
6.8	
6.9	
7.0	
7.1	
7.2	
7.3	
7.4	
7.5	
7.6	
7.7	

7) Bobbin Coil Voltage - Leak Rate Correlation

- o The Data Base is Very Small. Predictions of Leakagf May Be Significantly in Error.
  - The Data Base has Been Increased from 28 Datum to 34,
    - 3 Plant L Pulled Tubes
    - 3 Model Boiler Samples
  - Statistical Analysis of the Prediction Interval Accounts for Sample Size
  - Model Boiler Data Conservatively Represents Pulled Tube Population
  - Large Scatter Obtained by Merging Model Boiler and Pulled Tube Data Conservatively Widens the Prediction Interval
  - Lack of Data in the 0. to 0.1 L/Hr Range Could be a Source of Error. Including Non-Leakers with 90% or Higher Crack Penetration is Judged to Minimize the Potential for Significant Error.

oConcern/Suggestion
-Response

SLB Leak Rate Comparisons
CRACKFLO Calc's

Strength (ksi)	Temperature (deg F)	Crack Length (in)	Leak Rate (gpm)
68.8(typ)	577(hot)	0.1	
		0.2	
		0.3	
		0.4	
		0.5	
75.5(typ)	70(cold)	0.1	
		0.2	
		0.3	
		0.4	
		0.5	

Cases Compared	Crack Length (in)	Difference (%)
	0.1	
	0.2	
	0.3	
	0.4	
	0.5	

SLB Leak Rate - Bobbin Voltage Regression Analysis

First Order Regression

a,c

SLB Leak Rate Versus Bobbin Voltage
(7/8X0.050 Inch Tubing)

SLB Leak Rate, l/hr

SLB Leak Rate Versus Bobbin Voltage
(7/8X0.050 Inch Tubing)

[9]

SLB Leak Rate. l/hr

SLB Leak Rate Versus Bobbin Voltage
(7/8X0.050 Inch Tubing)

[ ] g

SLB Leak Rate, l/hr

Calculation of Leak Rate

a,c

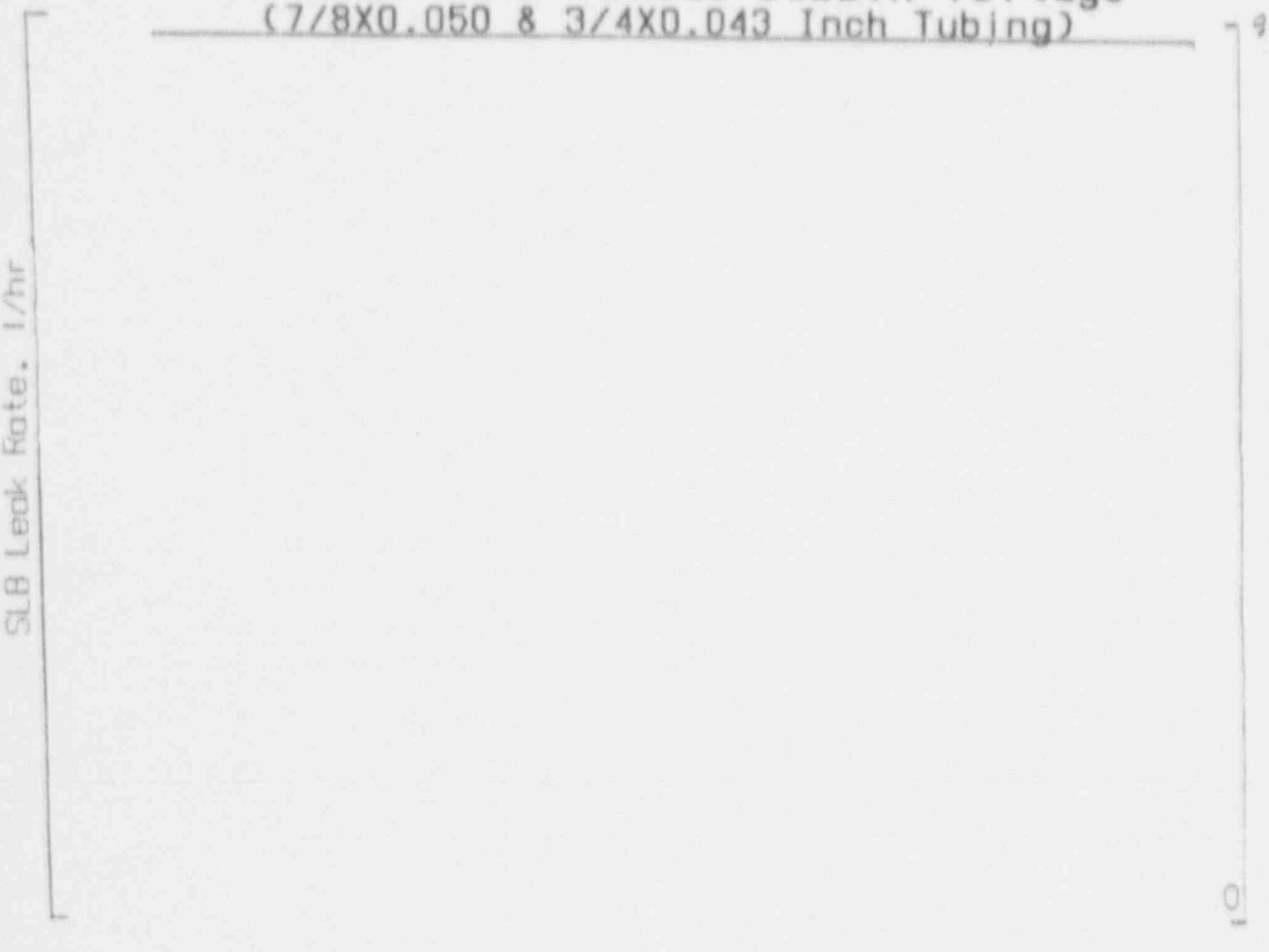
a, c

[ ] a,c

FARLEY 89-90 TSP/ALTERNATE PLUGGING CRITERIA LEAKAGE SLB 7/8 SG C

LEAK RATE(GMP)	CUMULATIVE PROBABILITY [g]
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1.0	
1.1	
1.2	
1.3	
1.4	
1.5	
1.6	
1.7	
1.9	
2.4	
2.5	
3.1	
3.2	
3.3	
3.4	
3.6	
3.8	
4.7	
5.1	
7.0	
7.1	
7.5	
9.5	
11.2	
11.5	
16.3	
72.6	

SLB Leak Rate Versus Bobbin Voltage
(7/8X0.050 & 3/4X0.043 Inch Tubing)



SLB Leak Rate Comparisons
CRACKFLO Calc's

Tube Size (in)	Strength (ksi)	Temperature (deg F)	Crack Length (in)	Leak Rate (gpm)
7/8	68.8(typ)	577(hot)	0.1	[
			0.2	
			0.3	
			0.4	
			0.5	][g]
3/4	77.7(typ)	577(hot)	0.1	[
			0.2	
			0.3	
			0.4	
			0.5	][g]

Cases Compared	Crack Length (in)	Difference (%)
	0.1	[
	0.2	
	0.3	
	0.4	
	0.5	][g]

SLB Leakage Rate
Cumulative Probability

Farley 2, SG C

- 7/8 inch data

  0.3 gpm at 90%

- 7/8 and 3/4 inch data

  0.5 gpm at 90%