ENCLOSURE
(W03 960206 800)

Sequoyah Nuclear Plant

Unit 1 Cycle 7 Refueling Outage

September - November 1995

RESULTS OF STEAM GENERATOR TUBE INSERVICE INSPECTION
(AS REQUIRED BY TECHNICAL SPECIFICATION SECTION 4.4.5.5.b)

RESULTS OF C-3 STEAM GENERATOR TUBE INSPECTIONS AND
RESULTS OF INVESTIGATIONS CONDUCTED TO DETERMINE
CAUSE OF TUBE DEGRADATION AND CORRECTIVE MEASURES
(AS REQUIRED BY TECHNICAL SPECIFICATION SECTION 4.4.5.5.c)

RESULTS OF ALTERNATE PLUGGING CRITERIA IMPLEMENTATION
(AS REQUIRED BY COMMITMENT FROM TECHNICAL
SPECIFICATION CHANGE 95-15)

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INTRODUCTION

During the scheduled Sequoyah Nuclear Plant (SQN) Unit 1 Cycle 7 (U1C7) refueling outage extensive inservice inspections were conducted in all four steam generators (SGs). The results of the inspections were classified as C-2 for SG 1. SGs 2, 3, and 4 were classified as C-3 due to the detection of primary water stress corrosion cracking (PWSCC) at the explosively expanded (WEXTEX) hotleg top-of-tubesheet (TTS) expansion zone region of the tubes. Alternate plugging criteria was implemented during this inspection due to the detection of outside diameter stress corrosion cracking at tube support plate intersections.

A total of three tubes were pulled, two were pulled from SG 1 for the implementation of the voltage based alternate tube plugging criteria and one tube was pulled from SG 2 to support structural integrity evaluation for top of tubesheet primary water stress corrosion cracking.

This report fulfills the reporting requirements of SQN Technical Specification section 4.4.5.5.b for reporting results of SG inservice inspection and section 4.4.5.5.c to provide information on investigations conducted to determine the cause of SQN Unit 1 SG tube degradation including details of nondestructive examinations (NDE), results of examinations, and corrective measures to prevent recurrence.

This report fulfills the reporting requirements of SQN Technical Specification Change 95-15 commitment to provide results, distributions and evaluations within 90 days of the Unit restart.

SG TUBE INSERVICE INSPECTION SCOPE AND RESULTS

The SQN SG tube Inservice Inspection (ISI) initial sample for bobbin coil probe inspection was 100% of the tubes full length in each SG (except for SG 1, where approximately 17.5% of the cold leg in rows 1 through 10 from the 7th support cold leg to the cold leg tube end were not examined). The initial sample in SGs 1 and 2 for dented tube support plate (TSP) intersections (>5 volts by bobbin coil) was 100%. In SGs 3 and 4 the initial sample was 100% of the dented TSP intersections at the first and second hotleg TSP intersections and 20% of the third TSP intersections. The initial sample for row 1 and 2 U-bend examination with RPC was 20 percent in each SG. The initial sample for the rotating pancake coil (RPC) examination of the WEXTEX transition region was approximately 48 percent of the hotleg tubes in each SG. Due to the detection of expansion transition PWSCC, the RPC examination scope was expanded to 100% in SGs 2, 3 and 4.

Table 1 summarizes the SQN U1C7 eddy current testing inservice inspection exams and summarizes the results of exams conducted. Table 2, Steam Generator Tubing Inservice Inspection Resolution of Defective Tubes and All Service Induced Wall Loss Indications, for the SQN U1C7 Outage, provides a summary of the tube damage detected and a characterization of the damage morphology.

The significant SG tube degradations detected were 1) TTS PWSCC, 2) Outside Diameter Stress Corrosion Cracking (Circumferential) at dented TSP intersections, 3) Outside Diameter Stress Corrosion Cracking (ODSCC) at non dented TSP intersections, and 4) axial PWSCC at dented TSP intersections. TTS RPC exams detected the longest circumferential crack of 336° (R15 C23) in SG 2 and a circumferential crack of 281° (R14 C41) in SG 4. These two tubes are located in the central region of the tube bundle where WEXTEX degradation is most likely due to high tube temperatures at the top of tubesheet and exasperated by sludge deposits creating an insulating effect. Figures 1 and 2 includes the terrain plots of the two previously identified tubes that are the most important TTS circumferential indications.

Circumferential cracking was detected at dented tube support plates with a total of 24 indications being reported. The distribution by SG and tube support plate elevation is provided in the table below. Of the 22 indications reported at the first tube support plate, 15 were in the pulser zone. Three indications were determined to be greater than 100° arc length. The largest indication crack angles for dented tube support plates were 110°, 127°, and 233°. The largest circumferential indication was R2 C13 of SG 4. The RPC data evaluation indicated that the total crack angle was 233°, the average depth over the crack angle was 89%, and the average depth over 360° was 59%. This tube started leaking during the end of the chemical cleaning process. It is believed that this indication started as a preexisting circumferential ODSCC of limited circumferential extent and was propagated due to the fatigue from the pressure pulse chemical cleaning process. Similarly, R1 C69 of SG 3 which had an arc angle of 127° was also in the pulser region where cracks would propagate due to Pressure Pulse Chemical Cleaning.

Circumferential Cracking at Dented Tube Support Plates				
SG	**H01**	**Pulser Zone H01**	**H02**	**H03**
1	7	1	0	0
3	9	9	0	0
4	6	5	1	1
Totals	22	14	1	1

ODSCC was detected at non-dented intersections during the Unit 1 Cycle 7 outage and Alternate Plugging Criteria was implemented. A total of 49 indications were identified and 45 were left in service. ODSCC is due to a caustic tube support plate crevice environment, where impurities concentrate to initiate axial stress corrosion cracking. A detailed report containing the 90 day reporting criteria is discussed later in this report.

Primary side axial cracking was also detected at dented tube support plate intersections in both less than and greater than 5 volts (bobbin coil). A total of 38 axial PWSCC indications were identified in dented TSP intersections, and 7 of these were found to extend outside the thickness of the TSP. Table 3 contains a listing of indications at dented tube support plates. All axial indications identified in dents less than 5 volts were structurally insignificant. Six of the 7 had a total crack length of less than 0.4 inches and were judged to be within Regulatory Guide (RG) 1.121 requirements. The most limiting indication, R11 C71 of SG 3, had a crack length of 0.53" extending beyond the TSP, with a maximum depth of 100% throughwall for 0.1", and an average depth of 71% over the length of the exposed crack (by eddy current depth profile analysis). This tube was determined, by structural analysis, to exhibit a burst pressure of approximately 6120 psi, which is within the requirements of RG 1.121.

A small number of other tubes were removed from service due to Anti-Vibration Bar wear, outside diameter corrosion (pit-like or volumetric indications), and three tubes were preventively plugged surrounding the tube that separated during removal in SG 2. These are identified in Table 1.

TABLE 1
SUMMARY OF SEQUOYAH UNIT 1 CYCLE 7
SG EDDY CURRENT INSPECTION/TUBE PLUGGING RESULTS

EDDY CURRENT EXAM TYPE	S/G 1	S/G 2	S/G 3	S/G 4	Totals
Full-length bobbin coil	2773	3357	3328	3325	**12783**
Partial-length bobbin coil	588	0	0	0	**588**
Support plate MRPC	540	154	2095	4477	**7266**
Top of tubesheet MRPC	2062	3357	3328	3325	**12072**
U-Bend MRPC	38	38	40	38	**154**
TOTAL EXAMS COMPLETED	6001	6906	8791	11165	**32863**
INDICATIONS (TUBES)	S/G 1	S/G 2	S/G 3	S/G 4	**Totals**
Defects (>=40% wall loss)					
HTS PWSCC	5	46	18	23	**92**
TSP PWSCC (DENTS)	2	1	16	19	**38**
OD TSP (AXIAL)	2	0	2	0	**4**
OD TSP CORROSION (CIRC)	7	0	10	7	**24**
OD INDICATION	0	1	1	0	**2**
AVB WEAR	0	0	0	1	**1**
Degradation (>=20% and <40% wall loss and APC indications)					
DIST BC SIGNAL	12	6	2	2	**22**
COLD LEG WASTAGE	3	0	4	0	**7**
FLOW LANE BLOCKING WEAR	2	0	1	1	**4**
OD INDICATION	1	2	0	0	**3**
AVB WEAR	3	7	9	7	**26**
MANUFACTURING FLAWS	2	2	0	3	**7**
PI (APC) OD CORROSION (Note 1)	8	6	22	9	**45**
Imperfections (<20% wall loss)					
COLD LEG WASTAGE	3	1	4	0	**8**
FLOW LANE BLOCKING WEAR	4	0	0	0	**4**
OD INDICATION	1	2	1	2	**6**
AVB WEAR	0	1	1	0	**2**
MANUFACTURING FLAWS	1	3	4	2	**10**
PLUGGING STATUS	S/G 1	S/G 2	S/G 3	S/G 4	**Totals**
Previously Plugged (as of U1C6)	27	31	60	63	**181**
Plugged Cycle 7					
HTS PWSCC	5	46	18	23	**92**
TSP PWSCC (DENTS)	2	1	16	19	**38**
OD TSP CORROSION (CIRC)	7	0	10	7	**24**
OD TSP CORROSION (AXIAL)	2	0	2	0	**4**
OD INDICATION	0	1	1	0	**2**
AVB WEAR	0	0	0	1	**1**
PREVENTIVELY PLUGGED	0	3	0	0	**3**
TOTAL TUBES PLUGGED	**43**	**82**	**107**	**113**	**345**

Note (1) SQN Unit 1 Technical Specfication Change 95-15 implemented an Alternate Plugging Criteria which allows TSP ODSCC indications to remain in service when less than 2 volt amplitude (bobbin coil)

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: **SQN Unit 1 Cycle 7** **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
1	1	1	26	HTS+17.75	FLBD	(1)
1	1	4	<40	HTS+.25	DIST BC SIGNAL	(1)
1	1	5	15	HTS+17.59	FLBD	(2)
1	1	79	SCI	H01+.38	ODSCC TSP CIRC	PLUG TUBE
1	1	90	25	HTS+17.80	FLBD	(1)
1	1	91	14	HTS+17.78	FLBD	(2)
1	1	92	15	HTS+17.70	FLBD	(2)
1	1	94	11	HTS+17.78	FLBD	(2)
1	2	46	PI	H01+.04	ODSCC TSP	(1)
1	3	47	<40	HTS+.11	DIST BC SIGNAL	[illegible]
1	3	51	<40	HTS+.09	DIST BC SIGNAL	[illegible]
1	3	58	<40	HTS+1.11	DIST BC SIGNAL	(1)
1	4	2	94	HTE+3.88	PWSCC HTS	PLUG TUBE
1	5	42	<40	HTS+.09	DIST BC SIGNAL	(1)
1	5	55	PI	H01-.04	ODSCC TSP	(1)
1	5	57	<40	HTS+1.18	DIST BC SIGNAL	(1)
1	6	26	PI	H01-.05	ODSCC TSP	PLUG TUBE
1	6	94	PI	H01+.04	ODSCC TSP	(1)
1	7	55	<40	HTS+1.31	DIST BC SIGNAL	(1)
1	7	93	<40	HTS+.09	DIST BC SIGNAL	(1)
1	8	2	23	C01-.08	C/L WASTAGE	(1)
1	8	26	PI	H01-.07	ODSCC TSP	(1)
1	8	60	SCI	H01+.36	ODSCC TSP CIRC	PLUG TUBE
1	8	89	<40	HTS+.13	DIST BC SIGNAL	(1)
1	9	55	PI	H01+.09	ODSCC TSP	PULL/PLUG
1	9	60	35	HTS+1.33	OD IND	(1)
1	9	69	27	H01+33.22	MFG FLAW	(1)
1	9	92	SAI	H01+.00	PWSCC TSP	PLUG TUBE
1	9	93	<40	HTS+.13	DIST BC SIGNAL	(1)
1	10	2	SCI	H01+.39	ODSCC TSP CIRC	PLUG TUBE

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
1	10	49	PI	H01+.00	ODSCC TSP	(1)
1	10	92	PI	H01-.02	ODSCC TSP	(1)
1	11	60	SCI	H01-.24	ODSCC TSP CIRC	PLUG TUBE
1	11	61	SCI	H01-.27	ODSCC TSP CIRC	PULL/PLUG
1	12	32	9	HTS+1.43	OD IND	(2)
1	12	51	SAI	H01-.03	PWSCC TSP	PLUG TUBE
1	12	61	SCI	H01-.28	ODSCC TSP CIRC	PLUG TUBE
1	15	64	SCI	HTS-.24	PWSCC HTS	PLUG TUBE
1	15	66	SCI	HTS-.17	PWSCC HTS	PLUG TUBE
1	20	47	<40	HTS+1.14	DIST BC SIGNAL	(1)
1	21	76	PI	H01+.00	ODSCC TSP	(1)
1	21	89	PI	H01+.02	ODSCC TSP	(1)
1	22	7	25	CTS+46.87	MFG FLAW	(1)
1	23	45	27	AV1+.07	AVB WEAR	(1)
1	23	45	23	AV3-.12	AVB WEAR	
1	25	42	SCI	HTS-.20	PWSCC HTS	PLUG TUBE
1	28	39	<40	HTS+2.11	DIST BC SIGNAL	(1)
1	28	43	SCI	HTS-.25	PWSCC HTS	PLUG TUBE
1	28	46	25	AV2+.07	AVB WEAR	(1)
1	28	46	21	AV3+.00	AVB WEAR	
1	28	50	28	AV1-.24	AVB WEAR	(1)
1	28	50	33	AV2-.17	AVB WEAR	
1	32	16	12	C01+.02	C/L WASTAGE	(2)
1	34	16	38	C01-.05	C/L WASTAGE	(1)
1	42	33	SCI	H01-.41	ODSCC TSP CIRC	PLUG TUBE
1	42	56	12	CTS+33.39	MFG FLAW	(2)
1	43	59	12	C01+.12	C/L WASTAGE	(2)
1	44	35	35	C01+.17	C/L WASTAGE	(1)
1	44	61	11	C01-.12	C/L WASTAGE	(2)

This sample's results have been classified as Category C-2

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
2	2	54	SAI	HTS-.13	PWSCC HTS	PLUG TUBE
2	2	55	22	CTS+29.53	MFG FLAW	(1)
2	3	73	SAI	HTS-2.64	PWSCC HTS	PLUG TUBE
2	4	39	SCI	HTS-.26	PWSCC HTS	PLUG TUBE
2	6	32	69	H01+.00	OD IND	PLUG TUBE
2	7	22	SCI	HTS-.24	PWSCC HTS	PLUG TUBE
2	8	14	<40	HTS-.03	DIST BC SIGNAL	(1)
2	8	32	PI	H01+.08	ODSCC TSP	(1)
2	9	72	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
2	10	31	SAI	H01+.00	PWSCC TSP	PLUG TUBE
2	10	36	SCI	HTS-.20	PWSCC HTS	PLUG/STABILIZE
2	10	37	SCI	HTS-.15	PWSCC HTS	PLUG TUBE
2	10	59	<40	HTS+1.75	DIST BC SIGNAL	(1)
2	10	64	<40	HTS+1.76	DIST BC SIGNAL	(1)
2	10	93	17	C02+45.24	MFG FLAW	(2)
2	12	34	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
2	13	4	PI	H02+.11	ODSCC TSP	(1)
2	13	26	SCI	HTS-.20	PWSCC HTS	PLUG TUBE
2	13	32	SCI	HTS-.15	PWSCC HTS	PLUG TUBE
2	13	33	<40	HTS+3.78	DIST BC SIGNAL	(1)
2	14	51	26	HTS+1.62	OD IND	(1)
2	15	22	SCI	HTS-.08	PWSCC HTS	PLUG TUBE
2	15	23	SCI	HTS-.19	PWSCC HTS	PULL/PLUG
2	15	36	11	HTS+1.22	OD IND	(2)
2	15	36	19	HTS+2.13	OD IND	
2	15	38	SCI	HTS-.16	PWSCC HTS	PLUG TUBE
2	16	32	<40	HTS+3.84	DIST BC SIGNAL	(1)
2	16	38	MCI	HTS-.16	PWSCC HTS	PLUG TUBE

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	16	44	PI	H01+.13	ODSCC TSP	(1)
2	16	73	SAI	HTS-1.15	PWSCC HTS	PLUG TUBE
2	17	26	MMC	HTS-.24	PWSCC HTS	PLUG TUBE
2	18	26	MCI	HTS-.21	PWSCC HTS	PLUG TUBE
2	18	28	SCI	HTS-.19	PWSCC HTS	PLUG TUBE
2	18	36	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
2	19	25	SCI	HTS-.14	PWSCC HTS	PLUG TUBE
2	19	26	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
2	19	49	SCI	HTS-.23	PWSCC HTS	PLUG/STABILIZE
2	19	51	SCI	HTS-.05	PWSCC HTS	PLUG TUBE
2	20	55	PI	H01+.11	ODSCC TSP	(1)
2	21	27	SCI	HTS-.29	PWSCC HTS	PLUG TUBE
2	21	30	MCI	HTS-.49	PWSCC HTS	PLUG/STABILIZE
2	21	35	<40	HTS+1.45	DIST BC SIGNAL	(1)
2	22	29	SCI	HTS-.24	PWSCC HTS	PLUG TUBE
2	23	30	SCI	HTS-.15	PWSCC HTS	PLUG TUBE
2	23	58	20	HTS+2.11	MFG FLAW	(1)
2	24	40	SCI	HTS-.14	PWSCC HTS	PLUG TUBE
2	25	31	17	AV1+.00	AVB WEAR	(2)
2	25	31	16	AV2-.30	AVB WEAR	
2	25	34	SCI	HTS-.08	PWSCC HTS	PLUG TUBE
2	25	66	SCI	HTS-.19	PWSCC HTS	PLUG TUBE
2	26	53	PI	H01+.05	ODSCC TSP	(1)
2	27	40	17	AV1-.05	AVB WEAR	(1)
2	27	40	21	AV2+.00	AVB WEAR	
2	28	19	PI	H01+.05	ODSCC TSP	(1)
2	28	43	18	AV2+9.92	MFG FLAW	(2)
2	28	52	SCI	HTS-.02	PWSCC HTS	PLUG TUBE
2	28	54	SCI	HTS-.26	PWSCC HTS	PLUG/STABILIZE
2	29	38	SCI	HTS-.12	PWSCC HTS	PLUG TUBE

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	20	49	SCI	HTS-.37	PWSCC HTS	PLUG TUBE
2	29	54	SCI	HTS-.11	PWSCC HTS	PLUG TUBE
2	29	59	SCI	HTS-.09	PWSCC HTS	PLUG TUBE
2	31	82	1	C01-.03	C/L WASTAGE	(2)
2	32	55	22	AV3-.22	AVB WEAR	(1)
2	33	18	22	H01+1.84	OD IND	(1)
2	33	49	34	AV2+.00	AVB WEAR	(1)
2	33	49	28	AV3+.00	AVB WEAR	
2	38	26	13	C02+10.04	MFG FLAW	(2)
2	38	46	31	AV3-.19	AVB WEAR	(1)
2	38	47	21	AV3+.00	AVB WEAR	(1)
2	38	48	25	AV3+.00	AVB WEAR	(1)
2	38	49	24	AV2+.00	AVB WEAR	(1)
2	38	49	21	AV3-.38	AVB WEAR	
2	43	63	19	H01+2.16	OD IND	(2)

This sample's results have been classified as Category C-3

1ST HTS EXPANSION

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	12	19	MCI	HTS-.05	PWSCC HTS	PLUG TUBE
2	15	80	SCI	HTS-1.62	PWSCC HTS	PLUG TUBE
2	16	5	SCI	HTS-.34	PWSCC HTS	PLUG/STABILIZE
2	17	21	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
2	19	23	SCI	HTS-.12	PWSCC HTS	PLUG TUBE
2	22	16	SAI	HTS-.49	PWSCC HTS	PLUG TUBE
2	32	37	SAI	HTS-.25	PWSCC HTS	PLUG TUBE
2	32	57	SCI	HTS-.17	PWSCC HTS	PLUG TUBE
2	41	49	SCI	HTS-.16	PWSCC HTS	PLUG TUBE
2	43	59	SCI	HTS-.09	PWSCC HTS	PLUG/STABILIZE

This sample's results have been classified as Category C-3

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
3	1	1	24	HTS+17.64	FLBD	(1)
3	1	5	<40	H07+8.69	DIST BC SIGNAL	(1)
3	1	61	PI	H01+.00	ODSCC TSP	(1)
3	1	85	SCI	H01-.06	ODSCC TSP CIRC	PLUG TUBE
3	2	74	SCI	H01-.26	ODSCC TSP CIRC	PLUG TUBE
3	2	77	PI	H01-.47	ODSCC TSP	PLUG TUBE
3	2	82	SCI	H01-.07	ODSCC TSP CIRC	PLUG TUBE
3	3	10	PI	H01+.07	ODSCC TSP	(1)
3	3	63	PI	H01+.00	ODSCC TSP	(1)
3	3	78	SCI	H01-.39	ODSCC TSP CIRC	PLUG TUBE
3	4	53	SCI	HTS+.00	PWSCC HTS	PLUG TUBE
3	4	54	SCI	HTS+.03	PWSCC HTS	PLUG TUBE
3	4	94	SCI	H01+.17	ODSCC TSP CIRC	PLUG TUBE
3	5	29	PI	H01+.02	ODSCC TSP	(1)
3	5	51	PI	H01-.02	ODSCC TSP	(1)
3	5	87	PI	H01+.00	ODSCC TSP	(1)
3	6	53	MCI	HTS-.15	PWSCC HTS	PLUG TUBE
3	6	57	SCI	HTS-.04	PWSCC HTS	PLUG TUBE
3	6	70	PI	H01+.00	ODSCC TSP	(1)
3	7	49	MCI	HTS-.07	PWSCC HTS	PLUG/STABILIZE
3	7	73	SCI	HTS-.23	PWSCC HTS	PLUG TUBE
3	7	91	PI	H02-.07	ODSCC TSP	(1)
3	8	11	SAI	H02+.42	PWSCC TSP	PLUG TUBE
3	8	18	SCI	HTS-.06	PWSCC HTS	PLUG TUBE
3	8	30	PI	H01+.02	ODSCC TSP	(1)
3	8	37	PI	H01-.02	ODSCC TSP	(1)
3	8	52	SCI	HTS-.05	PWSCC HTS	PLUG TUBE
3	8	58	SCI	HTS-.18	PWSCC HTS	PLUG TUBE

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	8	75	MCI	HTS-.24	PWSCC HTS	PLUG/STABILIZE
3	8	91	PI	H01+.00	ODSCC TSP	PLUG TUBE
3	9	76	SCI	HTS-.24	PWSCC HTS	PLUG TUBE
3	9	93	PI	H01+.02	ODSCC TSP	(1)
3	10	27	PI	H01+.02	ODSCC TSP	(1)
3	11	3	PI	H02+.00	ODSCC TSP	(1)
3	11	46	26	C01-.07	C/L WASTAGE	(1)
3	11	61	SCI	HTS-.12	PWSCC HTS	PLUG TUBE
3	11	71	SAI	H01-.55	PWSCC TSP	PLUG TUBE
3	12	62	PI	H01+.00	ODSCC TSP	(1)
3	12	63	<40	HTS+1.23	DIST BC SIGNAL	(1)
3	12	92	PI	H02-.02	ODSCC TSP	(1)
3	13	37	SAI	H01+.34	PWSCC TSP	PLUG TUBE
3	14	61	SAI	H01+.97	PWSCC TSP	PLUG TUBE
3	14	71	SAI	H01+.41	PWSCC TSP	PLUG TUBE
3	14	80	SAI	H02+.73	PWSCC TSP	PLUG TUBE
3	15	66	SCI	HTS-.29	PWSCC HTS	PLUG TUBE
3	16	45	SCI	HTS-.37	PWSCC HTS	PLUG/STABILIZE
3	17	64	SAI	H02+.13	PWSCC TSP	PLUG TUBE
3	18	50	SCI	HTS+.00	PWSCC HTS	PLUG TUBE
3	18	61	SAI	H01+.70	PWSCC TSP	PLUG TUBE
3	19	22	27	AV3+.29	AVB WEAR	(1)
3	19	36	PI	H01+.02	ODSCC TSP	(1)
3	21	9	16	H04+44.12	MFG FLAW	(2)
3	21	33	SAI	H01-.23	PWSCC TSP	PLUG TUBE
3	21	47	PI	H01+.05	ODSCC TSP	(1)
3	21	68	SAI	H01+.71	PWSCC TSP	PLUG TUBE
3	22	64	26	AV2+.49	AVB WEAR	(1)
3	22	64	23	AV2-.02	AVB WEAR	
3	22	64	32	AV3+.17	AVB WEAR	

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	22	67	24	AV2+.05	AVB WEAR	(1)
3	22	67	22	AV3+.25	AVB WEAR	
3	23	30	7	HTS+1.16	OD IND	(2)
3	23	75	93	H01+.00	OD IND	PLUG TUBE
3	26	48	SCI	HTS-.33	PWSCC HTS	PLUG TUBE
3	26	63	SCI	HTS-.18	PWSCC HTS	PLUG TUBE
3	26	67	SCI	H01+.30	ODSCC TSP CIRC	PLUG TUBE
3	27	84	21	C01+.07	C/L WASTAGE	(1)
3	28	66	18	AV3+.00	AVB WEAR	(2)
3	30	58	SCI	HTS-.30	PWSCC HTS	PLUG TUBE
3	31	70	PI	H01+.11	ODSCC TSP	(1)
3	33	16	36	C01+.05	C/L WASTAGE	(1)
3	33	70	SAI	H01+.23	PWSCC TSP	PLUG TUBE
3	34	67	14	C02+14.12	MFG FLAW	
3	34	67	18	C03+7.15	MFG FLAW	(2)
3	35	41	26	AV2-.05	AVB WEAR	(1)
3	35	69	22	AV3+.00	AVB WEAR	(1)
3	35	69	12	AV4-.05	AVB WEAR	
3	36	19	5	C01+.07	C/L WASTAGE	(2)
3	36	70	PI	H01-.02	ODSCC TSP	(1)
3	38	22	21	C01+.19	C/L WASTAGE	(1)
3	38	55	32	AV3+.00	AVB WEAR	(1)
3	38	55	30	AV3+.27	AVB WEAR	
3	38	62	21	AV4+.27	AVB WEAR	(1)
3	38	64	23	AV1+.00	AVB WEAR	(1)
3	38	64	38	AV2+.00	AVB WEAR	
3	38	64	30	AV3+.00	AVB WEAR	
3	39	56	14	CTS+4.66	MFG FLAW	(2)
3	41	64	28	AV1+.00	AVB WEAR	(1)
3	43	31	12	C01-.07	C/L WASTAGE	(2)

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	43	39	7	C02+45.58	MFG FLAW	(2)
3	44	61	19	C01+.05	C/L WASTAGE	(2)
3	45	58	5	C01+.05	C/L WASTAGE	(2)
This sample's results have been classified as Category C-3						
1ST PULSER ZONE TSP EXPANSION						
3	1	69	SCI	H01+.00	ODSCC TSP CIRC	PLUG TUBE
3	1	74	SCI	H01+.00	ODSCC TSP CIRC	PLUG TUBE
3	2	79	SCI	H01+.00	ODSCC TSP CIRC	PLUG TUBE
3	2	84	SCI	H01+.45	ODSCC TSP CIRC	PLUG TUBE
3	6	93	MMC	H01+.18	PWSCC TSP	PLUG TUBE
This sample's results have been classified as Category C-3						
1ST <5 VOLT DENTED TSP EXPANSION						
3	4	63	SAI	H01-.12	PWSCC TSP	PLUG TUBE
3	6	62	PI	H01-.01	ODSCC TSP	(1)
3	15	87	PI	H01-.14	ODSCC TSP	(1)
3	17	36	PI	H01-.12	ODSCC TSP	(1)
3	26	63	SAI	H01-.03	PWSCC TSP	
3	26	68	SAI	H01+.07	PWSCC TSP	PLUG TUBE
3	26	77	SAI	H01+.22	PWSCC TSP	PLUG TUBE
3	38	66	SAI	H01-.12	PWSCC TSP	PLUG TUBE

This sample's results have been classified as Category C-3

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
4	1	1	28	CTS+17.49	FLBD	(1)
4	1	13	SCI	H01+.38	ODSCC TSP CIRC	PLUG TUBE
4	1	39	SCI	H01-.38	ODSCC TSP CIRC	PLUG TUBE
4	1	75	SCI	H01+.00	ODSCC TSP CIRC	PLUG TUBE
4	2	13	SCI	H01-.19	ODSCC TSP CIRC	PLUG/STABILIZE
4	2	15	SCI	H02-.22	ODSCC TSP CIRC	PLUG TUBE
4	3	11	PI	H01+.16	ODSCC TSP	(1)
4	3	15	SCI	H01-.29	ODSCC TSP CIRC	PLUG TUBE
4	3	53	87	H01+.03	PWSCC TSP	PLUG TUBE
4	4	9	PI	H01+.06	ODSCC TSP	(1)
4	5	2	PI	H01+.00	ODSCC TSP	(1)
4	5	64	94	H01-.22	PWSCC TSP	PLUG TUBE
4	7	77	SCI	HTS+.00	PWSCC HTS	PLUG TUBE
4	8	30	SCI	HTS-.07	PWSCC HTS	PLUG TUBE
4	9	32	81	H03-.28	PWSCC TSP	PLUG TUBE
4	9	77	PI	H02-.05	ODSCC TSP	(1)
4	10	3	<40	H01+.99	DIST BC SIGNAL	(1)
4	11	82	29	C02+11.06	MFG FLAW	(1)
4	12	26	SCI	HTS-.13	PWSCC HTS	PLUG TUBE
4	12	28	SCI	HTS-.09	PWSCC HTS	PLUG TUBE
4	12	31	SCI	HTS-.10	PWSCC HTS	PLUG TUBE
4	13	39	SCI	HTS-.17	PWSCC HTS	PLUG TUBE
4	13	47	SCI	HTS-.06	PWSCC HTS	PLUG TUBE
4	14	26	14	HTS+4.35	OD IND	(2)
4	14	30	SAI	HTS-2.14	PWSCC HTS	PLUG TUBE
4	14	41	SCI	HTS-.04	PWSCC HTS	PLUG/STABILIZE
4	14	52	SCI	HTS-.10	PWSCC HTS	PLUG TUBE
4	14	82	23	C06+42.57	MFG FLAW	(1)
4	15	38	SCI	HTS-.01	PWSCC HTS	PLUG TUBE
4	15	48	SCI	HTS-.15	PWSCC HTS	PLUG TUBE
4	15	73	23	C01+16.24	MFG FLAW	(1)
4	15	75	17	C01+9.32	MFG FLAW	(2)
4	16	32	SCI	HTS-.06	PWSCC HTS	PLUG TUBE
4	16	45	SAI	H01+.41	PWSCC TSP	PLUG TUBE
4	17	46	66	H03-.58	PWSCC TSP	PLUG TUBE
4	17	63	SAI	H02-.02	PWSCC TSP	PLUG TUBE
4	18	27	SCI	HTS-.18	PWSCC HTS	PLUG TUBE

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

Outage: SQN Unit 1 Cycle 7 **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	18	41	SCI	HTS-.08	PWSCC HTS	PLUG/STABILIZE
4	18	46	SCI	HTS-.04	PWSCC HTS	PLUG TUBE
4	19	38	SCI	HTS-.07	PWSCC HTS	PLUG TUBE
4	19	39	SCI	HTS+.00	PWSCC HTS	PLUG TUBE
4	19	49	91	H01-.08	PWSCC TSP	PLUG TUBE
4	19	61	SCI	HTS-.02	PWSCC HTS	PLUG TUBE
4	20	46	SCI	HTS+.10	PWSCC HTS	PLUG TUBE
4	21	70	SAI	HTS-.31	PWSCC HTS	PLUG TUBE
4	22	44	SAI	HTS-.01	PWSCC HTS	PLUG TUBE
4	22	56	PI	H01-.16	ODSCC TSP	(1)
4	26	20	SAI	H02+.09	PWSCC TSP	PLUG TUBE
4	28	40	PI	H03+.00	ODSCC TSP	(1)
4	28	45	21	AV2+.00	AVB WEAR	(1)
4	28	47	27	AV2-.19	AVB WEAR	(1)
4	28	52	8	HTS+1.25	OD IND	(2)
4	29	31	17	AV1+.08	AVB WEAR	(1)
4	29	31	27	AV2+.33	AVB WEAR	
4	29	31	26	AV3+.33	AVB WEAR	
4	29	31	17	AV4+.44	AVB WEAR	
4	29	47	46	AV4-.40	AVB WEAR	PLUG TUBE
4	32	20	MAI	H02+.00	PWSCC TSP	PLUG TUBE
4	32	49	29	AV3+.03	AVB WEAR	(1)
4	34	16	SAI	H01+.14	PWSCC TSP	PLUG TUBE
4	35	25	95	H03+.73	PWSCC TSP	PLUG TUBE
4	35	43	26	AV2+.00	AVB WEAR	(1)
4	35	43	17	AV3-.05	AVB WEAR	
4	36	53	SAI	H01+.09	PWSCC TSP	PLUG TUBE
4	36	57	SAI	H01+.23	PWSCC TSP	PLUG TUBE
4	38	28	PI	H01+.03	ODSCC TSP	(1)
4	38	54	25	AV1+.00	AVB WEAR	(1)
4	38	54	37	AV2+.00	AVB WEAR	
4	39	55	6	AV2+.00	AVB WEAR	
4	39	55	23	AV3+.00	AVB WEAR	(1)
4	39	55	6	AV4+.00	AVB WEAR	
4	40	28	17	H04+36.05	MFG FLAW	(2)
4	42	32	69	H01+.08	PWSCC TSP	PLUG TUBE
4	42	43	<40	H01-.70	DIST BC SIGNAL	(1)

This sample's results have been classified as Category C-3

(1) Retest Future Outage

(2) None Required

TABLE 2

Resolution of Defective Tubes and All Service-Induced Wall Loss Indications

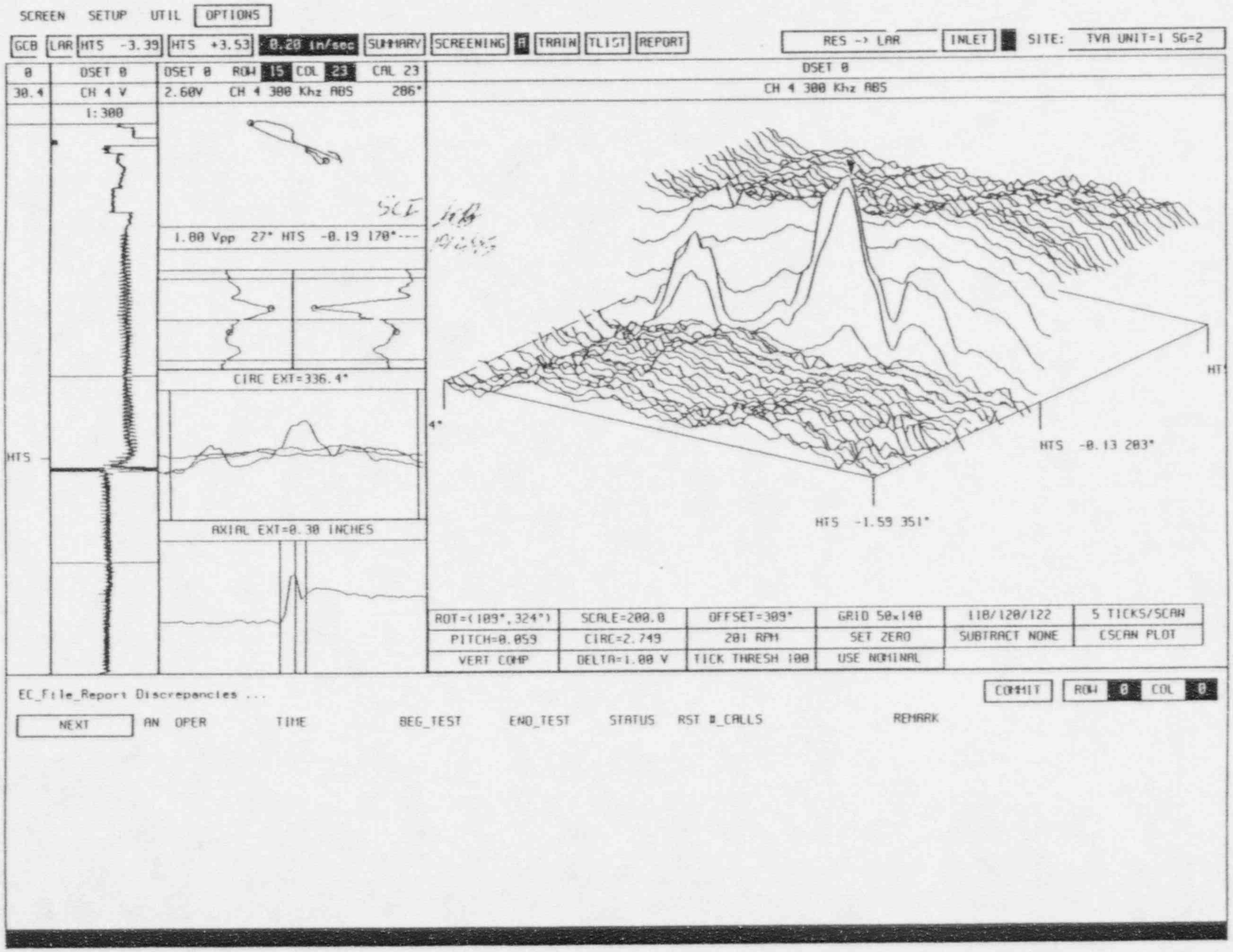
Outage: **SQN Unit 1 Cycle 7** **Date:** *26-Jan-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
1ST PULSER ZONE TSP EXPANSION						
4	1	18	SAI	H01+.38	PWSCC TSP	PLUG TUBE
This sample's results have been classified as Category C-2						
1ST HTS EXPANSION						
4	32	17	SAI	HTS-.10	PWSCC HTS	PLUG TUBE
This sample's results have been classified as Category C-2						
1ST >5 VOLT DENTED TSP EXPANSION						
4	4	41	SCI	H03+.19	ODSCC TSP CIRC	PLUG TUBE
This sample's results have been classified as Category C-2						
1ST <5 VOLT DENTED TSP EXPANSION						
4	8	48	SAI	H01-.01	PWSCC TSP	PLUG TUBE
4	10	69	PI	H01-.10	ODSCC TSP	(1)
4	11	73	SAI	H01-.05	PWSCC TSP	PLUG TUBE
4	14	63	PI	H02-.01	ODSCC TSP	(1)
4	28	15	SAI	H01+.00	PWSCC TSP	PLUG TUBE
4	30	15	SAI	H01+.18	PWSCC TSP	PLUG TUBE
This sample's results have been classified as Category C-2						

(1) Retest Future Outage

(2) None Required

FIGURE 1
ROW 15 COL 23 SG 2



HTS -3.39 HTS +3.53 0.20 in/sec

RES -> LAR SITE: TVA UNIT=1 SG=2

0 DSET 0
30.4 CH 4 V
1:300

DSET 0 ROW 15 COL 23 CAL 23
2.60V CH 4 300 Khz ABS 286°

1.00 Vpp 27° HTS -0.19 170°---

CIRC EXT=336.4°

AXIAL EXT=0.30 INCHES

DSET 0
CH 4 300 Khz ABS

HTS -1.59 351°

HTS -0.13 283°

ROT=(189°,324°)	SCALE=200.0	OFFSET=309°	GRID 50x140	118/120/122	5 TICKS/SCAN
PITCH=0.059	CIRC=2.749	201 RPM	SET ZERO	SUBTRACT NONE	CSCAN PLOT
VERT COMP	DELTA=1.00 V	TICK THRESH 100	USE NOMINAL		

EC_File_Report Discrepancies ...

ROW 0 COL 0

AN OPER TIME BEG_TEST END_TEST STATUS RST #_CALLS REMARK

SCI

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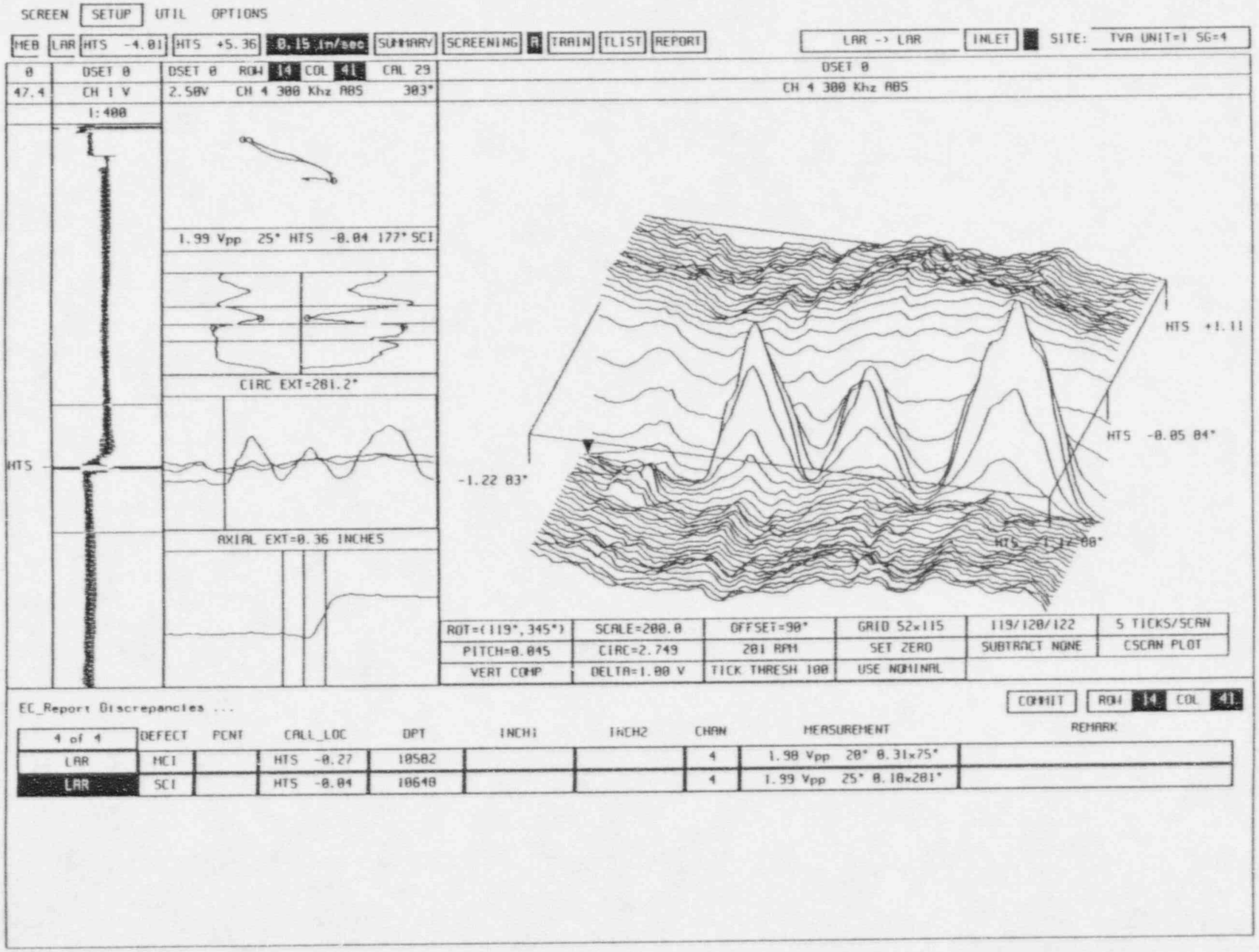
FIGURE 2
ROW 14 COL 41 SG 4



ROT=(119°,345°)	SCALE=200.0	OFFSET=90°	GRID 52x115	119/120/122	5 TICKS/SCAN
PITCH=0.045	CIRC=2.749	201 RPM	SET ZERO	SUBTRACT NONE	CSCAN PLOT
VERT COMP	DELTA=1.00 V	TICK THRESH 100	USE NOMINAL		

EC_Report Discrepancies ...

4 of 4	DEFECT	PCNT	CALL_LOC	DPT	INCH1	INCH2	CHAN	MEASUREMENT	REMARK
LAR	MCI		HTS -0.27	10502			4	1.98 Vpp 20° 0.31x75°	
LAR	SCI		HTS -0.04	10640			4	1.99 Vpp 25° 0.18x281°	

TABLE 3

SQN Unit 1 Cycle 7

PWSCC SAIs AND MAIs AT DENTED TUBE SUPPORT PLATES

< 5 VOLT DENTS					All Tubes will be plugged			
			Dent Size		Detected	"+ POINT "		
SG	Row	Col	>= 5 Volts	< 5 Volts	w/ Bobbin	% WALL	AXIAL EXT	INSIDE TSP
1	9	92		2.89	NDD	27	0.42	YES
3	11	71		2.02	YES	99	1.10	NO
3	21	33		3.3	NDD	34	0.36	YES
3	13	37		3.51	NDD	20	0.22	YES
3	14	71		3.74	YES	70	0.86	NO
4	1	18		2.96	YES	45	0.63	YES
4	3	53		2.95	YES	87*		YES
4	5	64		1.78	YES	94*		YES
4	9	32		4.98	YES	81*		YES
<5 VOLT DENT EXPANSION								
3	4	63		4.4	NDD	55	0.40	YES
3	26	63		4.6	NDD	20	0.27	YES
3	26	68		3.54	NDD	35	0.36	YES
3	26	77		2.49	NDD	30	0.31	YES
3	38	66		2.94	NDD	20	0.31	YES
<5 VOLT DENT EXPANSION								
4	8	48		3.52	NDD	20	0.27	YES
4	11	73		2.43	NDD	20	0.27	YES
4	17	63		4.5	NDD	35	0.27	YES
4	19	49		3.5	YES	20	0.31	YES
4	28	15		2.26	NDD	35	0.31	YES
4	30	15		2.4	NDD	20	0.27	YES
4	42	32		4.2	YES	30	0.27	YES
>5 VOLT DENTS								
1	12	51	5.6		NDD	48	0.42	YES
2	10	31	7.8		NDD	38	0.36	YES
3	8	11	5		NDD	22	0.72	YES
3	14	61	10.8		NDD	35	0.62	NO
3	14	80	15.6		NDD	50	0.36	YES
3	17	64	6.9		NDD	35	0.63	YES
3	18	61	10.5		NDD	55	0.49	NO
3	21	68	8.6		NDD	40	0.36	NO
3	33	70	6.6		NDD	25	0.22	YES
4	16	45	50.7		NDD	45	0.27	NO
4	17	46	22.7		YES	80	0.80	NO
4	26	20	5.3		YES	45	0.63	YES
4	32	20	5.2		YES	35	0.54	YES
4	34	16	5.48		NDD	44	0.27	YES
4	35	25	13.3		YES	40	0.49	YES
4	36	53	6.89		NDD	80	0.27	YES
4	36	57	5.92		NDD	65	0.31	YES
* Bobbin Coil % Throughwall								
j:\shared\u1c7\u1c7sai.xls								

ALTERNATE PLUGGING CRITERIA RESULTS

A report in accordance with Technical Specification Change 95-15 commitment for Alternate Plugging Criteria was prepared by Westinghouse Electric Corp. to provide results, distributions, and evaluations within 90 days of unit restart for the implementation of Alternate Plugging Criteria at SQN Unit 1. The Westinghouse report is Attachment 1.

DAMAGE MECHANISM ASSESSMENT AND TUBE PULL

The damage mechanism occurring on the inside diameter at the TTS transition and dented tube support plate intersections is Primary Water Stress Corrosion Cracking (PWSCC). Alloy 600 PWSCC is influenced by tensile stress, operational temperature, and a susceptible metallurgical structure in the presence of normal primary coolant water.

The metallurgical condition of all tubes with PWSCC detected at the WEXTEX expansion transitions was evaluated for the mechanical properties (tensile, yield, percent elongation, and Rockwell B hardness) relative to the average of all tubes in the SG. Generally, higher carbon contents in Alloy 600 imply a higher susceptibility to PWSCC.

Comparison of Carbon Content and Mechanical Properties					
	Carbon	Tensile	Yield	Elongation	Hardness
	(%)	(KSI)	(KSI)	(%)	(B)
Average of All SQN SGs	0.034	102.26	56.35	38.40	87
Average of all tubes with TTS PWSCC	0.03	101.90	56.04	39.00	87

Tube with TTS expansion zone PWSCC in the SQN Unit 1 SGs do not have significantly different mechanical properties than the average tubes in the SQN SGs.

An assessment of the location of TTS PWSCC cracks was obtained by evaluating, by zones, the distribution of cracks (axial and circumferential) within the SGs and is listed below:

	Number of Cracks in Zones									
	Zone 1		Zone 2		Zone 3		Zone 4		Total in SG	
SG	Axial	Circ.	Axial	Circ.	Axial	Circ.	Axial	Circ.	Axial	Circ.
1								4	0	4
2		2		1	2	5	4	33	6	41
3								18	0	18
4	1						3	19	4	19
Total	1	2		1	2	5	7	74	10	82
Total / zone	3		1		7		81		92	
Percent	3.3%		1.1%		7.6		88.0%			

Results of the SQN U1C7 examinations show zone 3 and 4 contained 95.6% of all axial and circumferential expansion zone PWSCC. Zone 3 and 4 , being located in the center section of the SG, would operate at a higher temperature and be insulated by the sludge pile further raising the tube temperatures and driving the kinetics of TTS PWSCC.

A sample of tubes from each SG with TTS PWSCC were reviewed for internal diameter tubesheet expansion transition profiles. Evaluations of the expansion transition profiling plots identified the majority of the circumferential PWSCC detected was associated with oversized tubesheet hole conditions that produce transitions with changes in diameter of greater than 15 mils and/or irregularly shaped (sharp or uneven) transitions. The table below is a sample of tubes from each SG with circumferential PWSCC.

Irregular Tubesheet Profile Evaluation			
SG	**Tubes with PWSCC and Profile data**	**Tubes with Oversized holes and/or Irregular Expansions**	**Percent of Tubes with Oversized holes and/or Irregular Expansions**
1	2	1-OH 0-IR	1 of 2 50%
2	21	17-OH 1-IR	18 of 21 86%
3	9	3-OH 0-IR	3 of 9 33%
4	6	5-OH 0-IR	5 of 6 83%
Totals	**38**	**26-OH** **1-IR**	**27 of 38** **71%**

The tube pulled for top of tubesheet Primary Water Stress Corrosion Cracking will be discussed in this section. Tubes pulled for alternate plugging criteria will be discussed in the section on Alternate Plugging Criteria.

One tube (R15 C23) was pulled from Steam Generator 2 for a top of tubesheet inside diameter (ID) circumferential indication. The TTS region fractured during the tube pulling process. Field eddy current data (3 coil RPC) for the TTS region of R15 C23 determined an ID circumferential indication measuring 336° circumferential extent. The +Point probe measured the same location to have multiple circumferential indications with a total circumferential involvement of 316°. Figure 3 is the crack profile by blind NDE (3 coil RPC) verses actual destructive examination results. NDE results show good correlation with metallurgical Scanning Electron Microscopy (SEM) results.

Due to the fracturing of the tube during the pulling process, leak and burst testing were not able to be performed.

The calculated burst pressure from the destructive analysis results is approximately 7800 psi, which is well within the structural integrity requirements of Regulatory Guide 1.121.

SEM fractography was performed on the fracture face of tube R15 C23. The ID origin corrosion averaged 26% throughwall around the circumference with a maximum depth of 88%. The corrosion was comprised of 5 separate macrocracks. SEM examinations showed no nearby, separately nucleated, corrosion cracks parallel to the fracture face on the tube ID surface. Depth profiling of the indication is presented in Table 4. This simple corrosion morphology is typical of primary water stress corrosion cracking. There were no markings on the tube OD to identify the TTS relative to the fracture face and significant tube elongation prevented a precise dimensional analysis of the pre-pull fracture face elevation.

Based on the pulled tube analysis, NDE characterization of the TTS expansion transition conditions, chemistry, and metallurgical condition of the Alloy 600 tubes, it was concluded that the damage mechanism is PWSCC originating in the WEXTEX expansion transitions. In addition, 95.6% of the time indications occur in zones 3 and 4, and have a higher probability in tubes with oversized diameter tubesheet hole conditions.

FIGURE 3
ROW 15 COL 23 SG 2

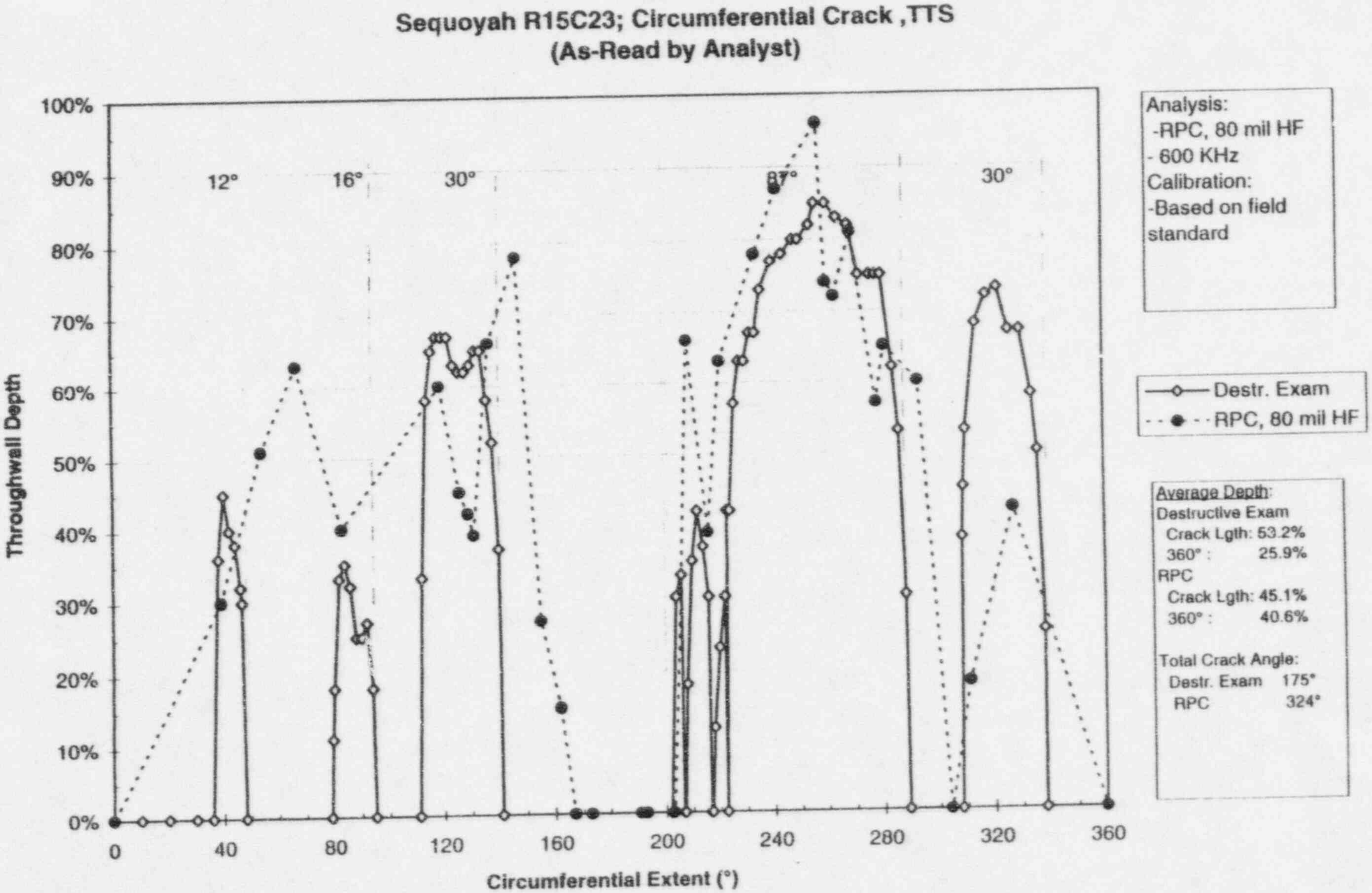


TABLE 4
ROW 15 COL 23 SG 2

Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Depth Profiles for ID Origin Corrosion

Tube No., Location	Length vs. Depth (degrees / % throughwall)	Ductile Ligament Location / Width (inches)	Comments
R15C23, Near TTS	00/00		
	10/00		
	20/00		
	30/00		
	(36/00) <== Macrocrack 1 Tip		
	40/41		Macrocrack 1 Length = 10 degrees
	(46/00) <== Macrocrack 1 Tip		
	50/00		
	60/00		
	70/00		
	(79/00) <== Macrocrack 2 Tip		
	80/16		Macrocrack 2 Length = 16 degrees
	(90/23)		
	(94/00) <== Macrocrack 2 Tip		
	100/00		
	110/00		
	(111/00)<== Macrocrack 3 Tip		
	120/66		Macrocrack 3 Length = 31 degrees
	130/67		
	140/44		
	(142/00)<== Macrocrack 3 Tip		
	150/00		
	160/00		
	170/00		
	180/00		
	190/00		
	200/00		
	(202/00)<== Macrocrack 4 Tip		

TABLE 4 (CONTINUED)
ROW 15 COL 23 SG 2

Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Depth Profiles

Tube No., Location	Length vs. Depth (degrees / % throughwall)	Ductile Ligament Location / Width (inches)	Comments
R15C23, Near TTS	(204/34)		
	(206/00)<== Ligament 1	<== Ligament 1 / 0.005" wide	
	210/42		
	(211/41)		
	(216/00)<== Ligament 2	<== Ligament 2 / 0.008" wide	Macrocrack 4 Length = 86 degrees
	220/25		
	(221/00)<== Ligament 3	<== Ligament 3 / 0.003" wide	
	230/63		
	240/75		
	250/77		
	(253/00)<== Ligament 4	<== Ligament 4 / 0.012" wide	
	260/81		
	(264/88)<== Maximum Crack Depth		
	270/75		
	280/72		
	(288/00)<== Macrocrack 4 Tip		
	290/00		
	300/00		Macrocrack 5 Length = 30 degrees
	(308/00)<== Macrocrack 5 Tip		
	310/50		
	320/69		
	330/64		
	(338/00)<== Macrocrack 5 Tip		
	340/00		
	350/00		
	(Average Macrocrack Depth = 26% Throughwall over 360 degrees; There were no 100% throughwall areas; Max. Crack Depth = 88% Throughwall at 264 degrees.)		

CIRCUMFERENTIAL GROWTH RATES

To determine a circumferential crack growth rate, a review was performed of past examinations for all tubes identified at the SQN Unit 1 Cycle 6 outage where PWSCC was initiated. This review was performed with knowledge that a defect was present and to determine if the defect was present in previous examinations. The table below is comparative data for 79 tubes with circumferential indications previously examined with RPC during the prior outage. The average circumferential crack growth rate from Cycle 6 to Cycle 7 was 47.5°, with a minimum of 0° and a maximum of 185°.

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	**Row**	**Column**	**Location**	**U1C7-deg**	**U1C6-deg**	**DELTA**
1	15	64	HTS	79	46	33
1	15	66	HTS	89	63	26
1	25	42	HTS	89	88	1
1	28	43	HTS	63	33	30
2	4	39	HTS	74	NDD	74
2	7	22	HTS	80	74	6
2	9	72	HTS	106	69	37
2	10	36	HTS	141	123	18
2	10	37	HTS	79	50	29
2	12	19	HTS	78	50	38
2	12	19	HTS	64	42	22
2	12	34	HTS	87	NDD	87
2	13	26	HTS	101	NDD	101
2	13	32	HTS	114	NDD	114
2	15	22	HTS	75	NDD	75
2	15	23	HTS	336	284	52
2	15	38	HTS	93	NDD	93
2	16	38	HTS	162	60	62
2	17	21	HTS	80	66	14
2	17	26	HTS	75	NDD	75
2	18	26	HTS	117	63	54
2	18	28	HTS	76	57	19
2	18	36	HTS	88	NDD	88
2	19	23	HTS	60	NDD	60
2	19	25	HTS	100	56	44
2	19	26	HTS	80	73	7
2	19	49	HTS	185	NDD	185
2	19	51	HTS	112	NDD	112
2	21	27	HTS	59	NDD	59
2	21	30	HTS	160	144	16

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	Row	Column	Location	U1C7-deg	U1C6-deg	DELTA
2	22	29	HTS	87	63	24
2	23	30	HTS	68	48	20
2	24	40	HTS	71	NDD	71
2	25	34	HTS	93	67	26
2	25	66	HTS	91	71	20
2	28	52	HTS	85	NDD	85
2	28	54	HTS	162	NDD	162
2	29	38	HTS	92	NDD	92
2	29	49	HTS	74	NDD	74
2	29	54	HTS	101	27	24
2	29	59	HTS	70	NDD	70
3	4	53	HTS	114	NDD	114
3	4	54	HTS	45	40	5
3	6	53	HTS	63	NDD	63
3	6	53	HTS	66	NDD	66
3	6	57	HTS	63	NDD	63
3	7	49	HTS	173	NDD	173
3	7	73	HTS	80	NDD	80
3	8	18	HTS	70	65	5
3	8	52	HTS	113	105	8
3	8	58	HTS	39	NDD	39
3	8	75	HTS	154	162	0
3	9	76	HTS	74	71	3
3	11	61	HTS	51	52	0
3	15	66	HTS	70	NDD	70
3	16	45	HTS	171	55	116
3	18	50	HTS	58	NDD	58
3	26	48	HTS	50	51	0
3	26	63	HTS	49	NDD	49
3	30	58	HTS	51	40	9
4	7	77	HTS	76	66	10
4	8	30	HTS	70	63	7
4	12	26	HTS	35	37	0
4	12	28	HTS	67	61	6
4	12	31	HTS	61	NDD	61
4	13	39	HTS	93	84	9
4	13	47	HTS	96	NDD	96
4	14	41	HTS	281	271	10
4	14	52	HTS	51	70	0
4	15	38	HTS	105	NDD	105
4	15	48	HTS	55	NDD	55
4	16	32	HTS	67	58	9
4	18	27	HTS	68	56	12

Circumferential Indications @ HTS

				Extents measured in degrees		
S/G	Row	Column	Location	U1C7-deg	U1C6-deg	DELTA
4	18	41	HTS	205	201	4
4	18	46	HTS	76	73	3
4	19	38	HTS	92	NDD	92
4	19	39	HTS	45	NDD	45
4	19	61	HTS	50	41	9
4	20	46	HTS	64	67	0

Avg. = 47.50633

CORRECTIVE ACTIONS TO PREVENT REOCCURRENCE OF PWSCC RELATED TO TUBESHEET EXPANSION

The corrective actions that have been implemented to address top of tubesheet PWSCC was shotpeening. Shotpeening was implemented in the Unit 1 Cycle 5 outage on all non plugged tubes from the tube end throughout the explosive expansion region to 2 inches above the top of the tubesheet. Shotpeening applies compressive stresses on the inside surface with an effective depth of 4 to 7 mils. The expansion region internal surface stresses were changed from 40-45 ksi tensile stresses to 60 ksi compressive stresses. The change in stress state to compressive will provide margin against initiation of future PWSCC. Pre-existing cracks with depths greater than 4 mils will not be ameliorated by shotpeening and will have a reasonable probability of progressing to detectable flaws in future fuel cycles. Based on SQN Unit 1 and industry experience, it is projected that less than 5 percent of the tubes in SQN Unit 1 will be affected over the life of the plant, by expansion transition PWSCC. TVA's SQN Unit 1 SGs were the first explosively expanded tubesheet transitions in the world to be shotpeened. TVA has taken a aggressive approach by implementing shotpeening to prevent long-term SG tube degradation of SQN SGs due to PWSCC in the tubesheet expansion region. A number of tubes that experience expansion transition PWSCC during the U1C7 outage resulted from preexisting indications that were most probability greater than 4 mils during the initial shotpeening. The number of tube presently affected by expansion transition PWSCC is significantly below the 5 percent projection over the plant life.

During the U1C7 refueling outage SQN implemented SG chemical cleaning to address outside diameter stress corrosion cracking (ODSCC). TVA predicted that circumferential cracking would occur at dented tube support plates based on SQN Unit 1 and other plant experience. Chemical cleaning was implemented as a preventative measure to address circumferential cracking at dented tube support plates. The process that was used is the Westinghouse pressure pulse chemical cleaning which used the EPRI/SGOG chemical formulations. Qualification of the process was performed by Westinghouse and TVA to verify effectiveness in cleaning tube support plate crevices. TVA has taken an aggressive approach to ODSCC at the top of tubesheet and at both dented and non dented tube support plate intersections. TVA had the foresight to implement chemical cleaning based on a predictive model of ODSCC and to prevent early SG replacement.

10 CFR 50.59 SAFETY EVALUATION/REGULATORY GUIDE 1.121 ANALYSIS

A safety evaluation in accordance with the criteria of 10 CFR 50.59 and in accordance with the guidelines of Regulatory Guide 1.121 was prepared by Westinghouse Electric Corp. to evaluate the safety significance of continued operation. Westinghouse Electric Corp. Safety Evaluation SECL-95-154 is Attachment 2.

Based on pulled tube destructive exam results and eddy current depth profiles the three top of tubesheet circumferential indications that exceeded 200° in arc length were determined to maintain burst integrity in excess of RG 1.121 recommendations at the end of Cycle 7.

CONCLUSIONS

The NDE testing completed on the SQN Unit 1 SGs and plugging of defective tubes met the Technical Specification and ASME Section XI code requirements for Inservice Inspection; therefore, each SG has been demonstrated operable.

Alternate Plugging Criteria was implemented in accordance with Technical Specification Change 95-15.

A detailed investigation of the SG TTS tube degradation detected during the Unit 1 Cycle 7 outage identified top-of-tubesheet expansion zone PWSCC of the Alloy 600 explosively expanded tubes as the damage mechanism.

The expansion transition PWSCC occurred in Alloy 600 tubes with average mechanical properties not significantly different than all heats of material used in the SQN Unit 1 SGs. Tubesheet expansion abnormalities such as larger diameter tubesheet holes or irregular profiles exhibit a general correlation to the incidence of PWSCC.

Based on the pulled tube analysis the top-of-tubesheet circumferential indication had segmented morphology with numerous ductile ligaments separating multiple crack initiation sites, which is typical of PWSCC. Material properties are consistent with those susceptible to PWSCC.

Shotpeening is not effective in preventing preexisting cracks (greater than 4 mils deep) from propagation, but will prevent new crack initiation, therefore the TTS PWSCC identified in Unit 1 Cycle 7 was incipient cracking at the time shotpeening was applied. Overall incidence of top-of-tubesheet PWSCC is within projected estimates.

Steam Generator Chemical Cleaning was implemented during the Unit 1 Cycle 7 outage as an ameliorative measure for ODSCC at both dented and non-dented tube support plate intersections to prevent future incidence of ODSCC at all tube locations.

Based on the criteria of 10 CFR 50.59 and utilizing the criteria of Regulatory Guide 1.121 TVA concluded that the integrity of the Sequoyah Nuclear Plant Unit 1 steam generators is maintained during Cycle 8, and does not represent an unreviewed safety question.

ATTACHMENT 1

WESTINGHOUSE ELECTRIC CORPORATION
SEQUOYAH NUCLEAR PLANT
CYCLE 8
ALTERNATE PLUGGING CRITERIA REPORT

WESTINGHOUSE PROPRIETARY CLASS 3

SG-96-01-007, Rev. 1

SEQUOYAH UNIT - 1

CYCLE 8 ALTERNATE PLUGGING CRITERIA 90 DAY REPORT

February 1996

Westinghouse Electric Corporation
Energy Systems Business Unit
Nuclear Services Division
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TABLE OF CONTENTS

SEQUOYAH UNIT - 1
CYCLE 8 ALTERNATE PLUGGING CRITERIA
90 DAY REPORT

1.0 INTRODUCTION

This report provides the Sequoyah Unit-1 steam generator tube support plate (TSP) bobbin voltage distribution summary, together with postulated Steam Line Break (SLB) leak rate and tube burst probability analysis results, in support of the implementation of the Alternate Plugging Criteria (APC) at End Of Cycle 7 (EOC-7) as outlined in the NRC Generic Letter GL 95-05, Reference 9.1. Calculations of leak rates and probability of tube burst are reported for the EOC-7 condition based on measured bobbin voltage distributions. Also provided are projections of bobbin voltage distributions, leak rates and burst probabilities for Cycle 8 operation. The methodology used in these evaluations is in accordance with the Sequoyah-1 plant-specific methodology presented in Reference 9-2 as well as the generic methodology described in Reference 9.3.

The application of the TSP APC at Sequoyah-1 steam generators (SG) involves a complete, 100% Eddy Current (EC) bobbin coil inspection of all hot leg TSP intersections in the tube bundles of four SGs and plugging of TSP indications greater than 2 volts which are confirmed by Rotating Pancake Coil (RPC). Also, RPC inspections are performed at certain locations exhibiting dent voltages and mixed residual signals. The measured bobbin signals are used to predict SG tube leak rate and probability of burst during a postulated SLB and show that they are within the allowable regulatory limits. Due to limited plant specific growth rate data for Sequoyah-1, a bounding growth rate distribution is applied for the Cycle 8 projections.

2.0 SUMMARY AND CONCLUSIONS

SLB leak rate and tube burst probability analyses were performed for the actual EOC-7 bobbin voltage distributions and projected voltage distributions for the EOC-8 condition at Sequoyah-1. SG 3 was found to be the limiting SG at EOC-7, and it is also projected to be the limiting SG for Cycle 8. The calculations demonstrate that APC application at EOC-7 (actual distribution) and EOC-8 satisfy NRC criteria for allowable leakage and burst probability.

Only a total of 49 indications were found in all four steam generators combined in the EOC-7 inspection, including six indications at dented intersections detected with the +Point probe. Of these, only two indications had a voltage above 2 volts. Those two indications plus five other bobbin indications below 2 volts were RPC inspected and confirmed as flaws. Two RPC-confirmed indications above 2 volts and two other indications below 2 volts were removed from service. Accordingly, 45 of the 49 indications were returned to service for Cycle 8. SG 3 with 24 indications had the largest number of indications reported at EOC-7. One of those indications had a bobbin voltage of 2.58 volts; it was RPC inspected, confirmed and removed from service. SG 1 had the largest indication reported at EOC-7, 2.69 volts; it was also RPC confirmed and removed from service.

The bounding estimates for SLB leak rate and burst probability calculated using the measured EOC-7 voltage distributions are 0.058 gpm and 1.32×10^{-5}, respectively. These values were calculated for SG 3 which is the limiting SG, and they are much lower than the allowable SLB leakage limit of 3.7 gpm and the NRC reporting guideline of 10^{-2} for the tube burst probability.

SLB leak rates and tube burst probabilities were also projected to EOC-8 conditions for all four SGs using a bounding growth rate distribution developed with data from 12 inspections for plants with 7/8" diameter tubes. Projections were made using both the NRC required constant POD value of 0.6 as well as the EPRI POD distribution. SG 3 was again found to be the limiting SG for Cycle 8 operation. SLB tube leak rate for SG 3 is projected to be 0.173 gpm and the burst probability is projected to be 2.55×10^{-5} at EOC-8. These results, based on a conservative POD value of 0.6, are also substantially lower than the Sequoyah-1 APC requirement for allowable leakage (3.7 gpm) and the NRC guideline of 1.0 E-02 for the burst probability.

Two hot leg tube segments removed from SG 1 (Tube R9C55, Tube R11C61), per GL 95-05 requirement, were examined at the Westinghouse Science and Technology center. Results from tube leak test, burst test and destructive examinations are summarized in Section 3. All burst pressures are well above burst margin guidelines of R.G. 1.121 and close to the mean of the burst pressure correlation. The pulled tube exam results were also evaluated for application to the EPRI database for APC application, and it was concluded that inclusion of the Sequoyah-1 data does not significantly affect the existing burst pressure and probability of leak correlations.

Chemical cleaning of the Sequoyah-1 steam generators was performed at this outage. The tube segments removed from SG 1 were examined to assess the effects of chemical cleaning, if any, on surface deposits at the TSP intersections. The tubes were found to be essentially free of significant deposits on the free span sections between TSPs, but deposits remained within TSP crevices. It is expected that the bobbin voltages are not significantly affected by chemical cleaning although there is no direct data to confirm this.

3.0 SEQUOYAH UNIT 1 PULLED TUBE DATA

3.1 Sequoyah-1 Pulled Tube Examination Results

3.1.1 Introduction

Two hot leg steam generator tube segments removed from Steam Generator 1 of Sequoyah Unit 1 (Tube R9C55, Tube R11C61) were examined at the Westinghouse Science and Technology Center primarily in support of alternative repair criteria (ARC) applications. A third tube (R15C23 from SG 2) was removed and examined for a circumferential indication in the WEXTEX transition but is not discussed in this report. The examination was conducted to characterize corrosion at steam generator hot leg tube support plate (TSP) crevice locations. The first and second TSP crevice regions (TSP1 and TSP2) of Tubes R9C55 and R11C61 were removed for examination. The TSP1 regions of Tubes R9C55 and R11C61 had original field eddy current calls of OD origin indications. Tube R11C61 had a field call of a circumferential crack based on +Point coil inspection (axial involvement indicated on all coils) at a 2.6 volt dented TSP intersection while R9C55 was reported as a bobbin indication, confirmed as an axial RPC indication, at the TSP intersection.

After nondestructive laboratory examination by eddy current, ultrasonic testing, radiography, dimensional characterization and visual examination, the two TSP1 regions were leak tested at elevated temperature. Subsequently, room temperature burst testing was conducted on the two leak tested TSP regions, as well as the remaining two non-leak tested TSP regions, and a free span (FS) section from the two tubes(R9C55 and R11C61) pulled for ARC applications. The four burst tested TSP specimens were destructively examined using SEM fractography techniques to characterize corrosion. In addition, two of the four TSP burst tested specimens were further examined using metallography.

3.1.2 NDE Results

Table 3-1 presents a summary of the more important field and laboratory NDE results.

The eddy current data were reviewed, including reevaluation of the field data, to finalize the voltages assigned to the indications and to assess the field no detectable degradation (NDD) calls for detectability under laboratory analysis conditions. A single analyst performed this work to minimize data variability. In general, field and laboratory eddy current inspections (bobbin probe and, in some cases, RPC and +Point probes) produced similar data for most regions examined. For the originally called field indication at TSP1 of Tube R9C55, there was little difference in the eddy current bobbin voltage calls between the reevaluated field and laboratory results. In the case of the originally called field indication at TSP1 of Tube R11C61, a circumferential indication was observed by RPC probe only; no indication was called from bobbin data. This indication was called circumferential based on + Point data although the pancake coils show significant axial extent. The reevaluation of the bobbin data showed a 53% deep, 0.96 volt distorted indication present in a 2.6 volt dent. (Detection by bobbin probe suggests that the indication had axial involvement and was more complex than a "pure" circumferential indication.) The field bobbin data for the remaining two original field NDD calls at TSP2 locations (Tubes R9C55 and Tube R11C61) were reevaluated and also found to be NDD. The reevaluated field RPC data for these two NDD calls continued to be NDD with no discernible flaw separable from the background level. In the laboratory, the TSP locations produced similar eddy current results to the reevaluated field data with the exception of the TSP2 region of Tube R11C61 where the +Point and Cecco probes suggested the presence of an indication.

Some increase in signal strength (voltage) was observed in the laboratory eddy current data due to the tube pulling operation. Field bobbin probe signal strengths for the TSP1 regions of Tubes R9C55 and R11C61 ranged from 1.0 to 2.69 volts while corresponding post-pull bobbin strengths were 4.5 volts for both TSP1 regions. The largest unambiguous increase was for TSP1 of Tube R9C55 where the bobbin probe signal strength increased from 2.69 volts to 4.5 volts (TSP1 of Tube R11C61 had its signal strength increase from a 0.96 volt DI to a 4.5 volt, distorted dent). Both cases are considered moderate signal increases suggesting that there was some tearing of ligaments between microcracks. In addition, dent signals, absent in the field eddy current data, were present in the laboratory data. These new dent signals were caused by the tube pull.

All TSP region NDE indications were confined to their crevice regions. Some of the field and laboratory eddy current TSP indications had considerable width in the RPC data, and also in the laboratory UT data, suggesting the possibility of intergranular cellular corrosion (ICC) or three dimensional intergranular attack (IGA) in addition to and in association with axial cracking. Laboratory UT data suggested that all four TSP regions had indications. (Destructive examination later found corrosion at all TSP crevice regions.)

The TSP1 region of Tube R11C61 had a circumferential indication by field and laboratory RPC data, and the detection of the indication by bobbin probe suggests axial involvement. Laboratory +Point and gimbaled +Point inspections confirmed the presence of circumferential appearing indications at this location, since the +Point probes force a directionality call upon the data. Laboratory UT identified both axial and circumferential indications. Laboratory profilometry showed that a 100^0 wide, 0.004 inch deep (radial) dent existed in the center of the crevice near the 90^0 location. The circumferential indication was located on the periphery of the dent stress field. Radiography showed that the circumferential indication was inclined 30^0 from a true circumferential position. The reported circumferential or oblique indication was present in a cellular patch within a axial crack morphology.

3.1.3 Leak, Burst and Tensile Testing

Two TSP crevice regions (the TSP1 regions of Tubes R9C55 and Tube R11C61), those which had original field eddy current indications, were leak tested at elevated temperature and pressure at conditions ranging from a simulated normal operating condition to a simulated steam line break condition. Neither developed leaks.

All four pulled TSP crevice regions and two free span regions were burst tested at room temperature at a pressurization rate of 2000 psi per second. The burst tests were performed simulating free span conditions with no TSP enveloping the indications. In addition, the two field indication specimens were tested using a bladder and foil for the burst tests with a "semi-constraint" condition which simulated the lateral constraint provided by the TSP located above the crack indication at prototypical spacing between TSPs. Results of the burst tests are presented in Table 3-2. All burst specimens developed axial burst openings. The openings for the TSP crevice region specimens were centered within the crevice regions. The circumferential positions of the burst openings in the support plate crevice region specimens were close to the location of the deepest laboratory UT indications. The eddy current RPC data does not provide an absolute circumferential position. All TSP specimens burst at high pressures. The lowest burst pressure for the TSP crevice regions (Tube R9C55, TSP1, the 2.69 volt field bobbin indication) was 7,104 psi, 68% of the burst pressure of its free span equivalent. Table 3-2 also presents room temperature tensile data obtained from FS sections of the pulled tubes. The tensile and burst strengths for the free span sections are typical for Westinghouse tubing of this vintage.

Following burst testing, a visual inspection showed the presence of wide-spread intergranular corrosion, confined to the crevice region, at all four TSP regions. For the TSP1 region of Tube R11C61, the visual examination identified both axial and apparent cellular corrosion with an oblique crack in the cellular patch being readily visible near the bottom of the crevice region with the axial burst opening passing through the network.

3.1.4 Destructive Examination Results

From post-burst test visual inspections, corrosion cracks were observed on all four of the TSP specimens and these specimens were destructively examined. Two of the four specimens selected for destructive examination were given a complete destructive examination that included SEM fractography of the burst openings and metallography of secondary corrosion. The other two were characterized by SEM fractography of their burst openings.

The burst fracture faces (FF) of the four TSP crevice region specimens were opened for SEM fractographic examinations. In addition, the circumferential crack network of TSP1, Tube R11C61 was fractured in the laboratory for additional SEM fractographic examinations. Table 3-3 presents the results of the fractographic data in the form of macrocrack length versus depth, macrocrack length/average and maximum depth, and the number/location/width of ductile or uncorroded ligaments found on the TSP fracture faces. The TSP burst openings occurred in axial macrocracks that were composed of numerous axially oriented intergranular microcracks of OD origin. Ductile ligaments separating the microcracks were present in two of the four examined TSP specimens. These two TSP regions with ductile ligaments (TSP2 of Tube R9C55 and TSP1 of Tube R11C61) had a typical number of remaining uncorroded ligaments between microcracks comprising the burst macrocracks. For the laboratory opened circumferential FF of the TSP1 region of Tube R11C61, the circumferential macrocrack similarly was composed of numerous circumferentially oriented microcracks of OD origin. No ductile ligaments were present on the macrocrack. All intergranular corrosion was confined to and centered within the crevice regions.

The burst opening corrosion macrocracks for the TSP crevice regions had maximum depths ranging from 24% to 58% throughwall, with average depths ranging from 13% to 38% throughwall and with macrocrack lengths ranging from 0.240 to 0.689 inch. For the TSP1 region of Tube R11C61, the axial burst macrocrack had an average depth of 30% over a length of 0.689 inches with a maximum depth of 46% while the connecting laboratory opened circumferential FF, the circumferential indication observed by NDE, had an average depth of 42% over a length of 0.499 inches (65^0) with a maximum depth of 54%. Table 3-3 provides the depth profile for the 0.459" on one side of the burst opening while the 0.04" on the other side of the burst opening was estimated to be about 20% depth (fractography not performed on this short length).

Two TSP regions were called bobbin NDD in the field. The maximum crack depths for these two locations were 24% for TSP2 region of Tube R9C55 and 42% for the TSP2 region of Tube R11C61. The corresponding average macrocrack depths were 13% and 30%, respectively.

Figures 3-1 to 3-4 present sketches of the TSP region crack distributions found by visual (30 × stereoscope) examinations. The sketches show the locations where cracks were found and their overall appearance, not the exact number of cracks or their detailed morphology. All TSP regions had their corrosion centered within and confined to the crevice regions.

Due to the complexities of the crack networks observed in the TSP regions, radial metallography was utilized, in addition to transverse metallography, to provide an overall understanding of the intergranular corrosion morphology for the two TSP regions that were selected for metallographic characterization. In radial metallography, small sections of the tube (typically 0.5 by 0.5 inch) are flattened, mounted with the OD surface facing upwards and then progressively ground, polished, etched and viewed from the OD surface towards the ID surface. Table 3-4 provides a summary of the metallographic data. It can be noted that the maximum depth for Tube R9C55, TSP1 from the transverse metallographic section was 72% compared to the maximum depth of 58% for the burst crack face (SEM fractography). In this case, the maximum crack depth did not contribute to the weakest macrocrack which burst. For the other TSP region, the maximum depth was found on the burst crack face.

From the metallographic examinations conducted on the TSP1 region of Tube R9C55, it was concluded that the dominant OD origin corrosion morphology was axial intergranular stress corrosion cracking (IGSCC). In addition, there was some intergranular cellular corrosion (ICC) found in association with the axial IGSCC. With an ICC morphology, a complex mixture of short axial and oblique angled cracks interact to form cell-like structures. Figure 3-5 provides an example of the corrosion morphology found at the TSP1 of Tube R9C55 by radial metallography at a depth 10% below the OD surface. With progressive radial grinding, it was shown that the axial IGSCC became even more dominant with depth (continued to 42% depth) while the ICC tended to disappear (oblique corrosion stopped at about 22% depth). Radial metallography conducted on the TSP1 region of Tube R11C61 showed a more complex crack network structure that was influenced by the TSP dent in one quadrant of the tube. In the mid-crevice region, on both sides of the 100^0 wide dent, axial IGSCC with some ICC was present. No corrosion was present in the dent. Near the bottom of the crevice region, near the periphery of the dent stress field, oblique crack networks were more dominant than the axial networks of the ICC morphology. Figure 3-6 provides an example of the corrosion morphology found at the TSP1 of Tube R11C61 by radial metallography at a depth 10% below the OD surface. The radial grinds for the TSP1 region of Tube R11C61 showed that the oblique crack networks had about the same depth (~50%, Table 3-4) as the axial networks. The more common form of ICC at non-dented intersections has deeper axial networks than circumferential networks, as found for the TSP1 region of Tube R9C55. Figure 3-7 repeats the Figure 3-3 sketch of the OD crack distribution for TSP1 of Tube R11C61 with the inclusion of a contour map of the dent as mapped by laser micrometry. The sketch shows the relationship of the corrosion to the dent. Finally, in some TSP crevice areas, especially where the cracking occurred at very high densities, shallow IGA also was present. The IGA always was significantly less deep than the surrounding ICC.

IGSCC morphology can be characterized by D/W ratios where the extent of IGA associated with a given crack is measured by the ratio of crack depth to the width of the crack at its mid-depth. D/W ratios greater than 20 are defined as minor and ratios less than 3 are defined as significant. Crack density is also considered an important parameter in characterizing corrosion. Crack densities greater than 100 cracks in 360 degrees are defined as high while values less than 25 are defined as low. The OD origin axial intergranular corrosion observed by metallography in the TSP1 crevice regions of the two Sequoyah Unit 1 tubes had little variation in crack densities or in crack morphologies. The crack density was medium and the crack morphology was moderate, as measured by D/W ratios. Note, that all individual D/W ratios that were low (D/W <3) were associated with very shallow cracks. As many shallow cracks were present, the reported average D/W ratios were lower than for the deeper, more significant, cracks. Table 3-4 presents a summary of the metallographic data. Specimen R9C55, TSP1 had the largest number of cracks (an estimated 55 cracks over the tube circumference for the center of the crevice region) with the cracking being rather uniformly distributed around the circumference.

3.1.5 Conclusions

All four of the TSP crevice regions of Tubes R9C55 and R11C61 had OD origin corrosion present. Metallographic data showed that the corroded TSP crevice regions had combinations of axially oriented IGSCC and ICC with the axial IGSCC predominating. In the case of the dented TSP1 region of Tube R11C61, the crevice region had combinations of axially and obliquely oriented IGSCC and ICC with both components having comparable depths. The oblique degradation occurred over one quadrant of the tube at the periphery of the dent stress field. In the middle of the crevice region, the more normal axial IGSCC was dominant. All TSP region corrosion was confined to the crevice regions. The corrosion morphology was typical of pulled tubes within the EPRI database with the principal difference for R11C61 being that the axial and oblique indications had comparable depths whereas the more common form of ICC (without denting) has axial indications deeper than the oblique indications.

Eddy current bobbin and other (RPC, +Point, gimbaled +Point, Cecco) probe data correlated well with the corrosion distribution for the deeper cracks. Two TSP crevice regions were called bobbin NDD in the field and one was subsequently found by +Point probes in the laboratory data to have an indication (TSP2 of Tube R11C61). Of the NDE techniques, laboratory UT provided the most accurate description of the TSP region corrosion, both in numbers of the TSP regions with corrosion (4 out of 4) and in the area extent and orientation of the corrosion. The two field NDD TSP regions had corrosion ranging from 24% to 42% throughwall maximum depth, with an average depth of 13% and 30% for the TSP2 regions of Tubes R9C55 and R11C61, respectively. Consequently, these locations had corrosion near the eddy current detection threshold, but above the UT detection threshold. In addition, the +Point probes did well in corrosion detection with the regular + point probe doing as well as the gimbaled +Point probe. However, the nature of a forced axial or circumferential call from the +Point probes can be misleading in interpreting the corrosion morphology as shown by the R11C61, TSP2 destructive examination results.

The TSP crevice region burst pressures ranged from 7,104 to 10,620 psi. All burst pressures were well above safety limitations required by R.G. 1.121 and close to free span burst values, i.e., those without corrosion. The burst pressures for tubes R9C55 and R11C61 at TSP1 are very close to the mean prediction for the burst pressure versus bobbin voltage correlation previously developed for axial ODSCC indications.

3.2 Comparison of RPC Depth Profiles with Destructive Examination Results

Although not a part of the ARC for ODSCC at TSP intersections, industry efforts are being applied to develop software and procedures for obtaining length versus depth profiles from RPC and +Point data. Eddy current analyses for the Sequoyah-1 indications were performed prior to the destructive examination of the tubes. The predicted depth profiles are compared with the destructive examination results in this section.

Figure 3-8 shows the comparison of the eddy current depth profiles with the destructive exam data for R9C55, TSP 1. Crack #2 of the eddy current data, which is the more limiting indication, should be compared with the destructive exam data. The destructive exam length of 0.44" compares well with the +Point length of 0.42" and the 3-coil RPC probe, axial coil data provides a more conservative length of 0.51". The destructive exam average depth of 41.4% is in good agreement with the +Point 43.9% while the axial coil data underestimates the depth with a 27.1% average.

Comparisons of eddy current and destructive exam data for the circumferential indication in R11C61, TSP 1 are shown in Figure 3-9. The + Point data of 66°, 54.0% crack average depth and 9.9% average depth over 360° (basis for structural integrity assessments) are also moderately conservative compared to 65°, 40.5% and 7.3% from the destructive exam. In the case, the 80 mil coil overestimates the crack angle (81°) while providing a good estimate of 8.5% for the 360° average depth.

Overall, these comparisons provide strong support for the depth sizing capabilities in support of structural integrity assessments. Depth sizing can be applicable to assessing tube integrity of large voltage indications. Bobbin voltage responds as an integral of all indications around the circumference of the tube and thus can be high compared to the equivalent voltage for a structurally limiting indication. Depth sizing can be used to more directly assess the structural integrity of the limiting crack. In addition, depth sizing permits structural assessment of indications found at dented intersections with > 5.0 volt dents for which the bobbin voltage cannot be assigned.

3.3 Sequoyah-1 Pulled Tube Evaluation for ARC Applications

The pulled tube examination results were evaluated for application to the EPRI database for ARC applications. The eddy current data were reviewed, including reevaluation of the field data, to finalize the voltages assigned to the indications and to assess the field NDD calls for detectability under laboratory conditions. The data for incorporation into the EPRI database were then defined and reviewed against the EPRI outlier criteria to provide acceptability for the database.

3.3.1 Eddy Current Data Review

Table 3-5 provides a summary of the eddy current data evaluations for the Sequoyah-1 pulled tubes. These NDE data results have been discussed in the above Section 3.1.2. As noted above, the field and laboratory reevaluations of the field bobbin data are in good agreement for the field call at R9C55, TSPs 1 and 2 (both NDD at TSP 2). The reevaluated field bobbin voltages, including the adjustment for cross calibration of the field ASME standard to the laboratory standard, are used for the EPRI ARC database. The reevaluation was performed by the same analyst that performed a large part of the EPRI pulled tube database and the use of these voltages minimizes analyst variability in the database, which is separately accounted for in ARC applications as an NDE uncertainty.

The indication at R11C61, TSP 1 requires further evaluation as this indication was called a 76° circumferential indication by +Point inspection, was bobbin NDD in the field call and has a 0.96 volt bobbin indication by laboratory reanalysis of the field data. The bobbin analysis for this indication is shown in Figure 3-10. Figures 3-11 to 3-13 show the RPC flaw shapes from the +Point, 80 mil pancake and 115 mil pancake coils respectively. The +Point response is typical of a circumferential indication while the 80 and 115 mil pancake coils show significant axial extent and could be called an axial indication if directional coils were not utilized. The +Point coil forces a decision of axial or circumferential and resulted in the circumferential call. It is seen from Table 3-3 that the axial burst opening is associated with a 0.689" long axial crack with the oblique (about 30° from horizontal) or circumferential crack found about 0.54" below the top of the axial crack. Both the axial burst and general crack pattern as shown in Figure 3-7 indicate that the dominant crack morphology is axial ODSCC with the deeper oblique crack associated with a patch of cellular corrosion (Figure 3-6). The cellular patch of Figure 3-6 is somewhat different from the cellular patches on non-dented tubes in that the oblique cracks are more numerous than the axial and the depth of the oblique cracks is about the same as the axial cracks (Table 3-4). The typical non-dented cellular patch, such as that on R9C55-TSP 1 (Table 3-4), has the axial cracks deeper than the oblique cracks. It is concluded that the crack morphology is dominantly axial and not substantially different from that in the EPRI database. Thus, the indication on R11C61, TSP 1 should be considered for inclusion in the EPRI database. It can be further noted that, if the bobbin indication had been called in the field at about 1 volt, the indication would have been left in service with inspection by RPC. For this reason, in addition to the dominantly axial morphology, the indication should be included in the EPRI database.

The TSP 2 indications on both tubes were found to be bobbin NDD in the field data. These indications are associated with maximum crack depths of 24% and 42% with average depths of 13% and 30%. The deeper and longer indication was found on R11C61, TSP 2. This indication was identified by +Point and Cecco in the laboratory inspection but not by 3-coil RPC. UT identified the indications on all four TSP intersections.

The Sequoyah-1 SGs were chemically cleaned prior to the tube pull at EOC-7. Visual examination for tube surface deposits indicates that the tubes were essentially free of deposits over the free span regions of the tubes between TSPs. The tube sections within the TSP crevices had OD deposits following the chemical cleaning and the tube pull operations. Some areas of the tubes within the TSP were essentially free of deposits but this is typical of pulled tubes for which deposits are scraped from the surface as a consequence of pulling the tubes through the TSPs and tubesheet. Therefore, no definitive statement about deposit removal at the TSPs can be made except it is clear that the chemical cleaning did not remove all deposits within the TSP crevices and the cleaning operations for the crevices were not as effective as for the free span sections of the tubing. There is no reason to believe that bobbin voltages were affected by the cleaning operations. The burst pressures for the indications are close to the mean of the burst pressure versus voltage correlation which would tend to indicate no significant effect of the cleaning on the voltages.

3.3.2 Sequoyah-1 Data for ARC Applications

The pulled tube leak test, burst test and destructive examination results are summarized in Table 3-6. Neither of the TSP 1 indications leaked at SLB conditions. Since the TSP 2 indications on both tubes are field bobbin NDD, these indications cannot be used in the EPRI ARC database for the voltage correlations.

The Sequoyah-1 pulled tube results were evaluated against the EPRI data exclusion criteria for potential exclusions from the database. Criteria 1a to 1e apply primarily to unacceptable voltage, burst or leak rate measurements and indications without leak test measurements. None of these criteria are applicable to the Sequoyah-1 indications. Criterion 3 applies to potential errors in the leakage measurements and is not applicable to the Sequoyah-1 indications with no leakage.

EPRI Criterion 2a applies to atypical ligament morphology for indications having high burst pressures relative to the burst/voltage correlation and states that high burst pressure indications with ≤2 uncorroded ligaments in shallow cracks < 60% deep shall be excluded from the database. Table 3-6 identifies the number of remaining ligaments and the maximum depths for the indications. The R9C55, TSP 1 indication has no ligaments with a maximum depth of 58%. However, the indication lies almost on the mean burst correlation and, therefore, does not qualify for exclusion from the database. The indication at R11C61, TSP 1 has 3 remaining ligaments and also does not satisfy Criterion 2a.

The indication at R11C61, TSP 1 does not meet the EPRI criteria for exclusion from the database, although, circumferential cracks are not included in the database. As discussed in Section 3.3.1, the crack morphology for this indication is dominantly axial and is typical of the EPRI database. Therefore, this indication is included in the database.

As shown in the last column of Table 3-6, the TSP 1 indications of R9C55 and R11C61 are to be included in the probability of leakage and burst correlations. This is further discussed in Section 3.4.

3.4 Comparison of Sequoyah-1 Data with Existing APC Correlations

This section reports on the evaluations performed which utilized the results of leak rate and burst testing of tube sections which were removed from Sequoyah Unit 1 in 1995. The results of the destructive examination of the tube sections is recorded in Section 3.1 of this report. The Sequoyah 1 pulled tube data germane to the APC correlations, and the bobbin amplitudes for APC applications, are given in Table

3-6. The results of the destructive examinations, e.g., leak and burst tests, are compared to the database[1] of similar test results for 7/8" outside diameter steam generator tubes. In addition, the effect of including the new test data in the reference database was evaluated. In summary, the test data are consistent with the database relative to the burst pressures and the probability of leak as a function of the bobbin amplitude. (No comparison of leak rates is possible since the specimens did not leak at the SLB pressure.) These comparisons and evaluations are discussed below.

3.4.1 Suitability for Inclusion in the Database

The report information on the destructive examinations of the tube sections was reviewed relative to the EPRI guidelines for inclusion/exclusion of tube specimen data in the alternate plugging criteria (APC) database, as discussed in Section 3.3. This review revealed no information that would lead to a conclusion that the data should not be included in the database. Therefore, the resulting correlations should be considered applicable to the use of APC to indications in 7/8" diameter tubes in Westinghouse SGs.

3.4.2 Burst Pressure vs. Bobbin Amplitude

Results from two (2) burst tests, performed on tube specimens which exhibited non-zero bobbin amplitudes at TSP elevation locations, were considered for evaluation. A plot of the burst pressures of the Sequoyah 1 specimens is depicted on Figure 3-14 relative to the burst pressure correlation developed using the reference database.[2]

1. A visual examination of the data relative to the EPRI database indicated that the burst pressures measured fall within the scatter band of the reference data. This is also apparent from the nearness of the data points to the reference regression line illustrated on Figure 3-14.

2. Both data points fall within a 90% non-simultaneous two-sided prediction band about the regression line (the one-sided 95% prediction curve depicted

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[1] The database consisted of the EPRI recommended database, as approved by the NRC in GL 95-05, plus test results from pulled tube sections removed from Beaver Valley 1 and Farley 2 in the Spring of 1995. Evaluations of those data were reported in SG-95-06-006 (May 1995) and SG-95-07-010 (July 1995).

[2] The database is not shown since it is proprietary to the Electric Power Research Institute.

is the lower bound of the two-sided 90% prediction band). Since a two-sided simultaneous prediction band for the two data points would be wider than the non-simultaneous band, no statistically significant anomalies are indicated.

In summary, the visual examination doesn't indicate any significant departures from the reference database.

Since the Sequoyah-1 burst pressure data were not indicated to be from a separate population from the reference data, the regression analysis of the burst pressure on the common logarithm of the bobbin amplitude was repeated with the additional data included. A comparison of the regression results obtained by including these data in the regression analysis is provided in Table 3-7. Regression predictions obtained by including these data in the regression analysis are also shown on Figure 3-14. A summary of the changes is as follows:

1. The intercept of the burst pressure, P_B, as a linear function of the common logarithm of the bobbin amplitude regression line is increased by 0.17%. This has the effect of increasing the predicted burst pressure as a function of the bobbin amplitude.

2. The slope of the regression line is increased by 0.26%, i.e., the slope is more steep. This has the effect of decreasing the burst pressure as a function of bobbin amplitude for large indications.

3. There is a decrease in the standard error of the residuals of 0.81%. The effect of this change would be reflected in a slightly smaller deviation of the 95% prediction line from the regression line.

The net effect of the changes on the SLB structural limit, using 95%/95% lower tolerance limit material properties, is to increase it by 0.2 volts, i.e., from 9.0 volts to 9.2 volts. The increase in the intercept and the decrease in the standard error coupled with the fact that the structural limit is also increased indicates that the probability of burst would also decrease for bobbin indications over the structural range of interest. Based on the small change in the structural limit, the change in the probability of burst would be expected to be not significant.

3.4.2 Probability of Leak

The data of Table 3-6 were examined relative to the reference correlation for the PoL as a function of the common logarithm of the bobbin amplitude. Figure 3-15 illustrates the Sequoyah 1 data relative to the reference correlation. All of the specimens exhibited PoL behavior commensurate with expectations indicated by the reference regression curve. Based on the visual examination, there is no significant evidence of irregular results, i.e., outlying behavior is not indicated.

In order to assess the effect of the new data on the correlation curve, the database was expanded to include the Sequoyah 1 data and a *Generalized Linear Model* regression of the PoL on the common logarithm of the bobbin amplitude was repeated. A comparison of the correlation parameters with those for the reference database is shown in Table 3-8. These results indicate:

1. A 0.9% reduction (larger negative value) in the *logistic* intercept parameter.
2. A 0.8% increase in the *logistic* slope parameter.
3. The absolute values of the parameters' covariance matrix changed by 0.0% to 0.4%.
4. The Pearson standard error increased by 0.1% from 0.621 to 0.622. This is a positive indicator since the ideal value would be 1.0, but is not judged to be significant.

In order to assess whether or not these changes are significant, the reference correlation and the new correlation were also plotted on Figure 3-15. An examination of Figure 3-15 reveals essentially no change, in an absolute sense, in the correlation over the entire range of the data. It is noted that when the total leak rate is determined using the leak rate to bobbin volts correlation, the resulting value can be quite insensitive to the form of the PoL function. Hence, the effect of the changes in the parameter values and variances is judged to be insignificant relative to the calculation of the expected total leak rate.

3.4.3 Leak Rate vs. Bobbin Amplitude

As previously noted, none of the specimens exhibited leakage at the SLB differential pressure. Since the reference correlation of leak rate to voltage exhibits a *p*-value of 6.5% for the slope parameter, the use of the correlation in performing Monte Carlo simulations to estimate the total leak rate is not considered to be justified, based on the requirements stipulated in the NRC Generic Letter for voltage based plugging criteria.

3.4.4 General Conclusions

The review of the effect of the Sequoyah 1 data indicates that the burst pressure and the probability of leak correlations to the common logarithm of the bobbin amplitude would not be significantly changed by the inclusion of the data. Therefore, it is likely that the conclusions relative to EOC probability of burst and EOC total leak rate based on correlations obtained using the reference database would not be significantly affected by repeating those analyses using an expanded database which includes the Sequoyah 1 test data.

Table 3-1
Comparison of NDE Indications Observed on Sequoyah Unit 1 Pulled S/G Tubes

Location	Field E/C	Lab E/C	Lab UT Data	Lab X-Ray
R9C55, TSP1	Bobbin: 2.69V (2.64V)* OD Ind, 74% deep RPC: MAI (MAI, 2 axial Inds, 40% &38% deep with volumetric involvement)* + Point: MAI(MAI, 73% & 64% deep)*	Bobbin: 4.5V OD Ind, 70% deep RPC: 2 axial Inds with volumetric involvement, 70% deep Cecco: two signals (5/24 coils, 75° & 2/24 coils, 30°) + Point: axial detection, 77% deep Gimbaled + Point: axial detection, 74% deep	85% deep axial OD Ind at 140°, 40% deep OD axial Ind at 65° and many, shallow volumetric Inds nearby	NDD at TSP (wide tube pull gouge at main UT Ind location), short circ. Ind 1.5 inch below TSP
R9C55, TSP2	Bobbin: NDD (NDD)* RPC: NDD + Point: NDD (NDD)*	Bobbin: 3.6V dent RPC: NDD Cecco: + Point: NDD Gimbaled + Point: NDD, noisy data	Short, shallow OD MAI 180 to 270° and 330°	NDD
R11C61, TSP1	Bobbin: NDD, 2.6V dent (0.96V OD DI, 53% deep, 2.6V dent)* RPC: No field analysis (81° with axial extent. max. depth 82%)* + Point: 76° Circ OD Ind (66° Circ OD, 73% max. depth)*	Bobbin: 4.5V distorted dent RPC: 70° Circ OD Ind, 30% deep, noisy data Cecco: Ind (6/24 coils, 90°) + Point: 75° Circ detection, 40% deep Gimbaled + Point: 75° Circ detection, 50% deep	50-60% deep Circ Ind from 319° through 0° to 37° & a shallow one from 190 to 242°; numerous shallow, axial Inds around crevice region	Circ Ind (30° from true circ.), 0.3 inch long, near 0° location; Ind at edge of 0.004" (radial) deep, 100° wide dent centered near 90°
R11C61, TSP2	Bobbin: NDD (NDD)* RPC or + Point: not inspected	Bobbin: 40V dent RPC: NDD Cecco: Ind (2/24 coils, 30°) + Point: axial Ind Gimbaled + Point: axial Ind, 40 to 67% deep	Short, shallow axial Inds at 0, 160, 210, 285 & 355°	NDD

( )* = Eddy current reevaluation of field data tapes. All bobbin voltages include cross calibration of ASME standard to reference lab standard.

Legend of Abbreviations:

Ind = Indication
RPC = Rotating Pancake Coil
MCI = multiple circumferential indications

SAI = single axial indication
MAI = multiple axial indications
V = volts

NDD = no detectable degradation
TSP = tube support plate

Table 3-2
Room Temperature Burst and Tensile Test Data for Sequoyah Unit 1 S/G Tubes

Location	Burst Pressure, psig	Burst Ductility, %	Burst Length, inches	Burst Width, inches	0.2% Offset Tensile Yield Strength, psi	Tensile Ultimate Strength, psi	Tensile Elongation, %
R9C55, FS	10,474	31.0	1.752	0.341	47,600	97,100	26.8+
R9C55, TSP1*	7,104	12.3	1.965	0.273			
R9C55, TSP2	10,459	26.7	1.551	0.368			
R11C61, FS	11,704	32.7	1.891	0.364	57,900	108,100	31.7
R11C61, TSP1*	10,063	15.6	1.443	0.364			
R11C61, TSP2	10,620	13.7	1.306	0.390			
Control, NX8161	11,426				53,600	108,500	29.2

Legend:

TSP = tube support plate; FS = free span; S/G = steam generator

* = Burst with foil and bladder in a semi-restraint condition, all others burst without restraint, bladder, or foil.

\+ = Failed outside gage length, reducing the measured ductility.

Table 3-3
Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R9C55, TSP1 (Axial Burst Crack)	0.00/00 0.04/38 0.08/44 0.12/48 0.16/51 0.20/53 0.24/58 <--(Max. depth = 58%) 0.28/58 0.32/40 0.36/40 0.40/25 0.44/00 (Ave. depth = 38%, Macrocrack Length = 0.440 inch)	Crack Top (located 0.147" below TSP top) Crack Bottom (Located 0.587" below TSP top)	The axially oriented burst macrocrack had no ductile ligaments with dimple rupture features occurring over more than 50% of their lengths.
R9C55, TSP2 (Axial Burst Crack)	0.00/00 0.02/05 0.04/13<---Ligament 1/0.011" wide 0.06/04<---Ligament 2/0.009" wide 0.08/11<---Ligament 3/0.001" wide 0.10/21 0.12/21<---Ligament 4/0.002" wide 0.14/22 0.16/24<--(Max. depth = 24%) 0.18/16<---Ligament 5 & 6/0.001 & 0.003" wide 0.20/20<---Ligament 7/0.003" wide 0.22/08 0.24/00 (Ave. depth = 13%, Macrocrack Length = 0.240 inch)	Crack Top (located 0.3" below TSP top) Crack Bottom (Located 0.54" below TSP top)	The axially oriented burst macrocrack had seven ductile ligaments with dimple rupture features occurring over more than 50% of their lengths.

Table 3-3 (Continued)
Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R11C61, TSP1 (Axial Burst Crack)	0.00/00 0.04/18<---Ligaments 1 & 2/0.005 & 0.012" wide 0.08/26 0.12/35 0.16/36<---Ligament 3/0.009" wide 0.20/36 0.24/30 0.28/17 0.32/33 0.36/24 0.40/36 0.44/34 0.48/34 0.52/44 (0.54/46)<--(Max. depth & Circ. crack location) 56/40 0.60/32 0.64/32 0.68/34 (0.689/00) (Ave. depth = 30%, Macrocrack Length = 0.689 inch)	Crack Top (located 0.723" above TSP bottom) Crack Bottom (located 0.034" above TSP bottom)	The axially oriented burst macrocrack, located at 300°, had three ductile ligaments with dimple rupture features occurring over more than 50% of their lengths.

Table 3-3 (Continued)
Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R11C61, TSP1 (Circumferential Crack to right of axial burst opening)	0.00/44<--300° Location	Crack FF Tip (located 0.183" above TSP bottom at the 300° position)	The circumferentially oriented crack had no ductile ligaments. In addition to the 0.459" of circumferential cracking (60°) present to the right of the axial burst opening, approximately 0.04" (5°) of the same circumferential crack extended to the left of the axial burst opening. The total circumferential crack was 0.499" long, or approximately 65°.
	0.02/44		
	0.04/46		
	0.06/46		
	0.08/30		
	0.10/24		
	0.12/40		
	0.14/40		
	0.16/49		
	0.18/44		
	0.20/49		
	0.22/48<--Approximate 360/0° Location		
	0.24/44		
	0.26/44		
	0.28/40		
	0.30/48		
	0.32/54<--(Max. depth = 54%)		
	0.34/44		
	0.36/48		
	0.38/38		
	0.40/40		
	0.42/36		
	0.44/18		
	(0.459/00)<--Approximate 30° Location (Ave. depth = 42%, Macrocrack Length = 0.459 inch)	Other Crack FF Tip (located to right of axial burst opening at approximately 30°)	

Table 3-3 (Continued)
Sequoyah Unit 1 S/G Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R11C61, TSP2 (Axial Burst Crack)	0.00/00	Crack Top (located 0.40" above TSP bottom)	The axially oriented burst macrocrack had no ductile ligaments.
	0.02/16		
	0.04/36		
	0.06/40		
	0.08/38		
	0.10/40		
	0.12/27		
	0.14/22		
	0.16/26		
	0.18/26		
	0.20/25		
	0.22/38		
	0.24/37		
	0.26/39		
	0.28/42<--(Max. depth = 42%)		
	0.30/36		
	0.32/35		
	0.34/28		
	0.36/10		
	(0.37/00) (Ave. depth = 30%, Macrocrack Length = 0.37 inch)	Crack Bottom (located 0.03" above TSP bottom)	

Table 3-4
Metallographic Data of Sequoyah Unit 1 Steam Generator Tubes

Specimen	Section Type	Number of Cracks	Section Length (Inch)	Cracks per Inch	Estimated Maximum Number of Cracks at Mid-crevice Location	Max./Avg. Depth (% Throughwall)	Max. Depth of ICC Transverse and Axial Components (% Throughwall in Radial Section)	Avg. D/W Ratio from Transverse Section
R9C55, TSP1	Transverse	52	2.59	20	55	72 / 31	10%<Oblique<38%	12
	Radial	20	0.30	67		depth = 2 %	Axial>58%	
	Radial	24	0.49	49		depth = 10 %		
	Radial	12	0.49	24		depth = 38 %		
	Radial	8	0.49	16		depth = 58 %		
R11C61, TSP1	Transverse	20	2.04	10	40	44 / 28	30%<Oblique<50%	10
	Radial	17	0.50	34		depth = 2 %	30%<Axial<50%	
	Radial	19	0.55	35		depth = 10 %		
	Radial	7	0.55	13		depth = 30 %		
	Radial	0	0.55	0		depth = 50 %		

Table 3-5. Summary of Sequoyah-1 Pulled Tube Eddy Current Results

Tube	TSP	Field Call		Lab. Reevaluation of Field Data					Post Pull Data				
		Bobbin Volts(1)	+ Pt. Volts	Bobbin Volts	ASME Cal.(2)	Bobbin Volts(3)	Depth	+ Pt. Volts	Bobbin Volts	RPC 3-Coil	+ Point	Cecco	UT
R9C55	1	2.69	2.0 v MAI	2.93	0.901	2.64	74%	2.0 v MAI	4.5	MAI	MAI	5 & 2 Coils	MAI
	2	NDD	NDD	NDD				NDD	NDD	NDD	NDD	NDD	MAI
R11C61	1	NDD 2.6 v Dent	0.5 v 76° SCI	1.06 2.6 v Dent	0.901	0.96	53%	0.5 v 66° SCI	4.5 Dented	70° SCI	75° SCI	6 Coils	MAI 78° SCI
	2	NDD	Not Insp.	NDD				Not Insp.	40 v Dent	NDD	SAI	2 Coils	MAI

Notes: 1. Field data include cross calibration of ASME standard to the reference laboratory standard

2. ASME calibration represents the cross calibration factor for the field ASME standard to the reference laboratory standar and is applied to the laboratory reevaluation to obtain the corrected APC volts

Table 3-6. Sequoyah-1 Pulled Tube Data for ARC Applications

Tube	TSP[1]	Bobbin Data		RPC Volts	Destructive Exam Results				Leak Rate-l/hr		Burst Pressure Data - ksi				Use in Corr. Note 5
		Volts	Depth		Max. Depth	Avg. Depth	Crack Length	No. Lig.[2]	N. O. 1300 psid	SLB 2560 psid	Meas. Burst Press.	σ_y	σ_u	Adj.[4] Burst Press.	
R9C55	1	2.64	74%	2.0	58%	38%	0.440"	0	0.0	0.0	7.104			7.364	B, POL
	2	NDD		NDD	24%	13%	0.240"	7	0.0[3]	0.0[3]	10.459			10.842	None
	FS										10.474	47.6	97.1	10.858	
R11C61	1	0.96	53%	0.5 66° SCI	46% Ax. 54% Circ.	30% Ax. 42% Circ.	0.689" Axial 65° Circ.	3 Ax. 0 Circ.	0.0	0.0	10.063 Axial			9.093	B, POL
	2	NDD		Not Insp.	42%	30%	0.37"	0	0.0[3]	0.0[3]	10.620			9.596	None
	FS										11.704	57.9	108.1	10.576	

Notes:

1. FS is freespan section of tubing with no tube degradation to obtain tensile properties and undegraded tubing burst pressure
2. Number of uncorroded ligaments with > 50% of ligament length remaining in burst crack face.
3. Inferred from destructive exam depth, leak test not performed. Corrosion depth too shallow for leakage at SLB conditions.
4. Burst pressures adjusted to 150 ksi for $\sigma_y + \sigma_u$.
5. B = data to be used in burst correlation, POL = data to be used in probability of leakage correlation, L = data to be used in leak rate correlation.

Table 3-7: Effect of Sequoyah 1 Data on the Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = \alpha_1 + \alpha_2 \log(\text{Volts})$$

Parameter	Reference[(1)] Database Value	Database with Sequoyah 1	Change
α_1	7.5990	7.6119	0.17%
α_2	-2.3534	-2.3594	0.26%
r^2	82.72%	82.70%	-0.02%
σ_{Error}	0.812	0.805	-0.81%
N (data pairs)	77	79	2
p Value for α_2	$3 \cdot 10^{-30}$	$5 \cdot 10^{-31}$	-82.2%
Reference σ_f	68.78 ksi[(2)]		

Notes:
(1) The reference database includes the results of data obtained from tubes removed from Beaver Valley 1 and Farley 2 in the Spring of 1995.
(2) This is the flow stress value to which all data was normalized prior to performing the regression analysis. This affects the coefficient and standard error values. The corresponding values for a flow stress of 75.0 ksi can be obtained from the above values by multiplying by 1.0904.

Table 3-8: Effect of Sequoyah 1 Data on the Probability of Leak Correlation

$$\Pr(\text{Leak}) = \left\{1 + e^{-[\beta_1 + \beta_2 \log(V)]}\right\}^{-1}$$

Parameter	Reference[(1)] Database	Database with Sequoyah 1	Change
β_1	-6.9280	-6.9901	0.9%
β_2	8.3834	8.4470	0.8%
V_{11} (2)	3.4663	3.4522	-0.4%
V_{12}	-3.8107	-3.8019	-0.2%
V_{22}	4.5466	4.5456	0.0%
DoF(3)	104	106	2
Deviance	25.12	25.18	0.3%
Pearson SD	62.1%	62.2%	0.1%

Notes:
(1) The reference database includes results obtained from tube sections removed from Beaver Valley 1 and Farley 2 in the Spring of 1995.
(2) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_i, of the regression equation.
(3) Degrees of freedom.

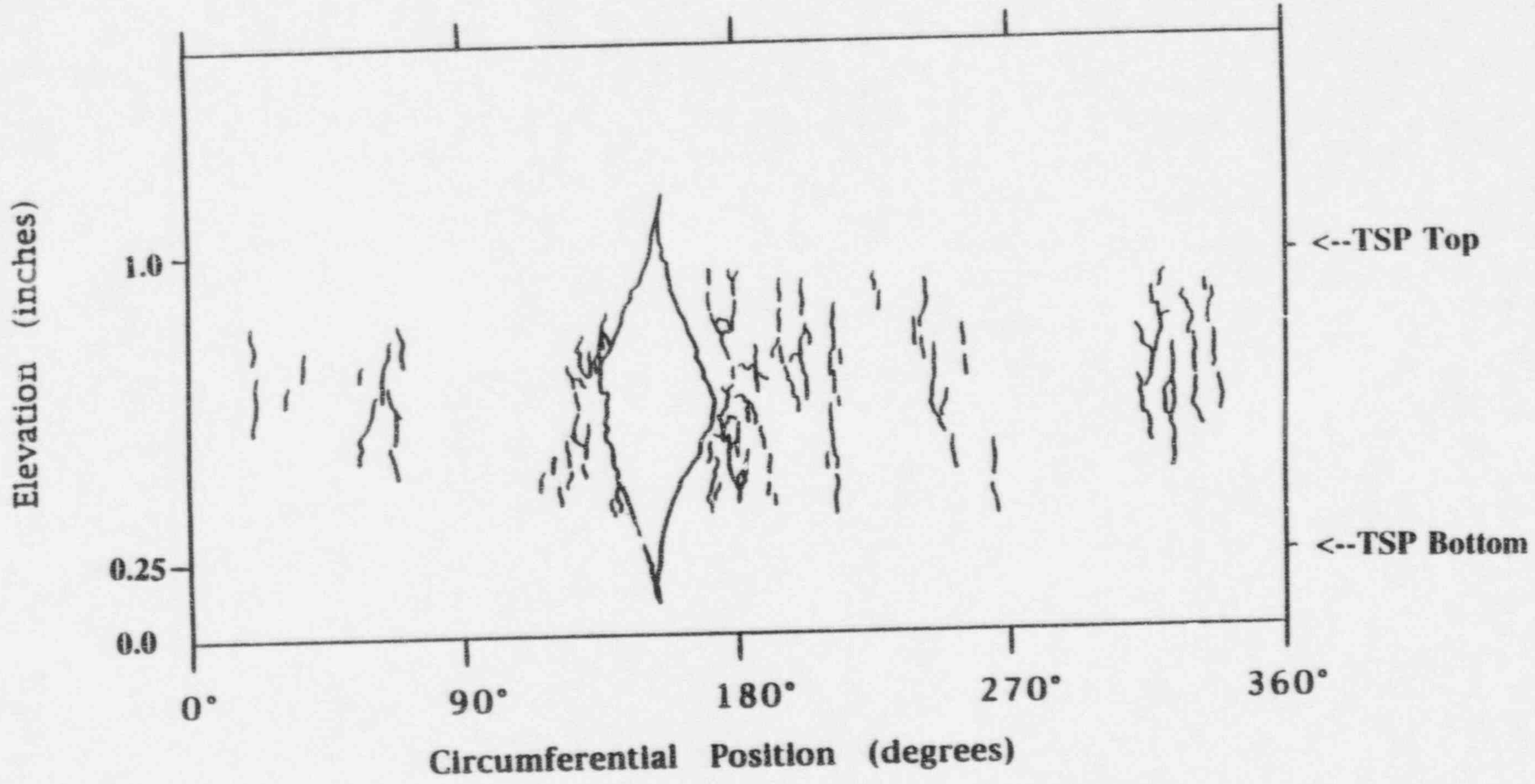


Figure 3-1 Sketch of the OD surface crack distribution found at the first tube support plate (TSP) of Tube R9C55. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

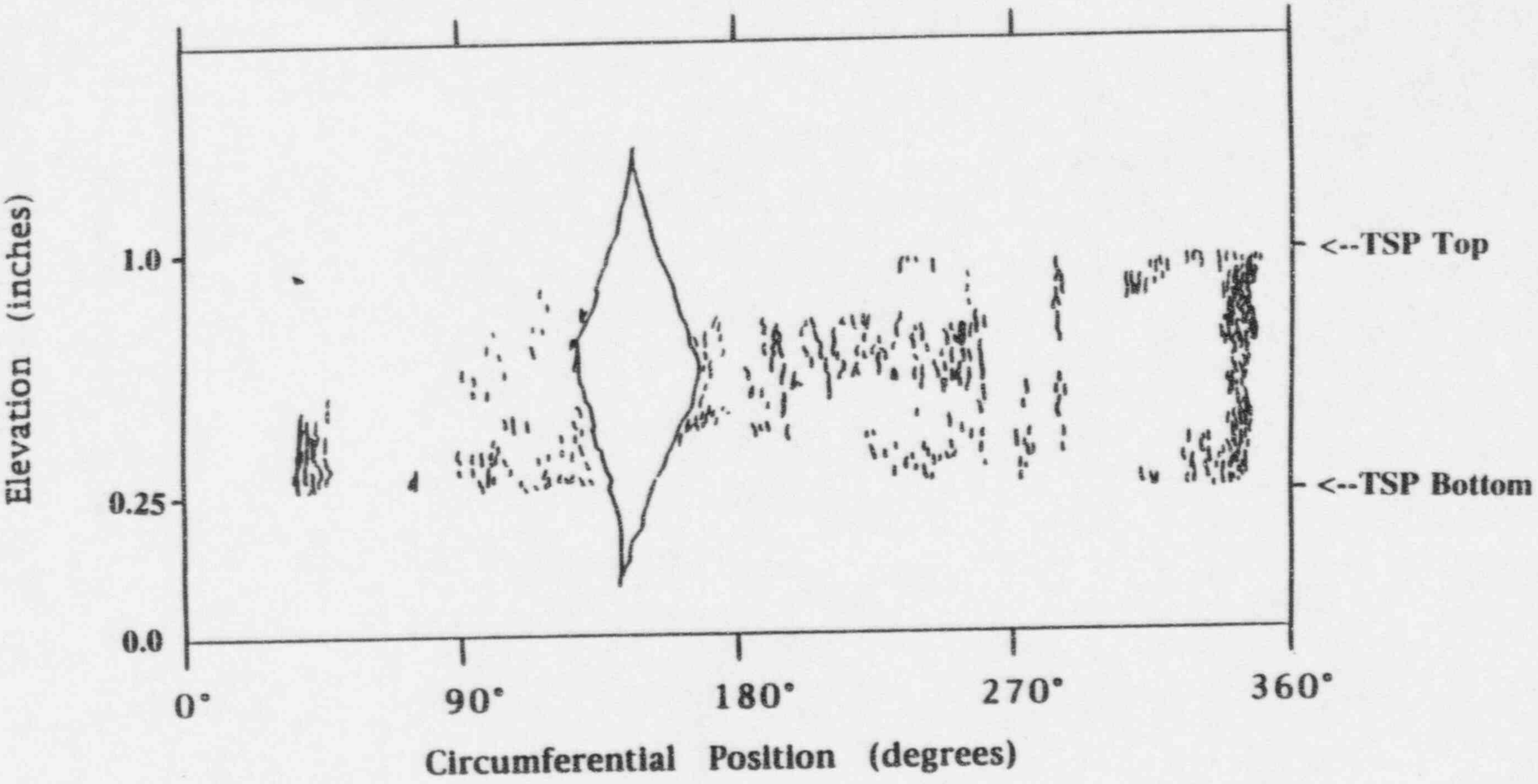


Figure 3-2 Sketch of the OD surface crack distribution found at the second tube support plate (TSP2) of Tube R9C55. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

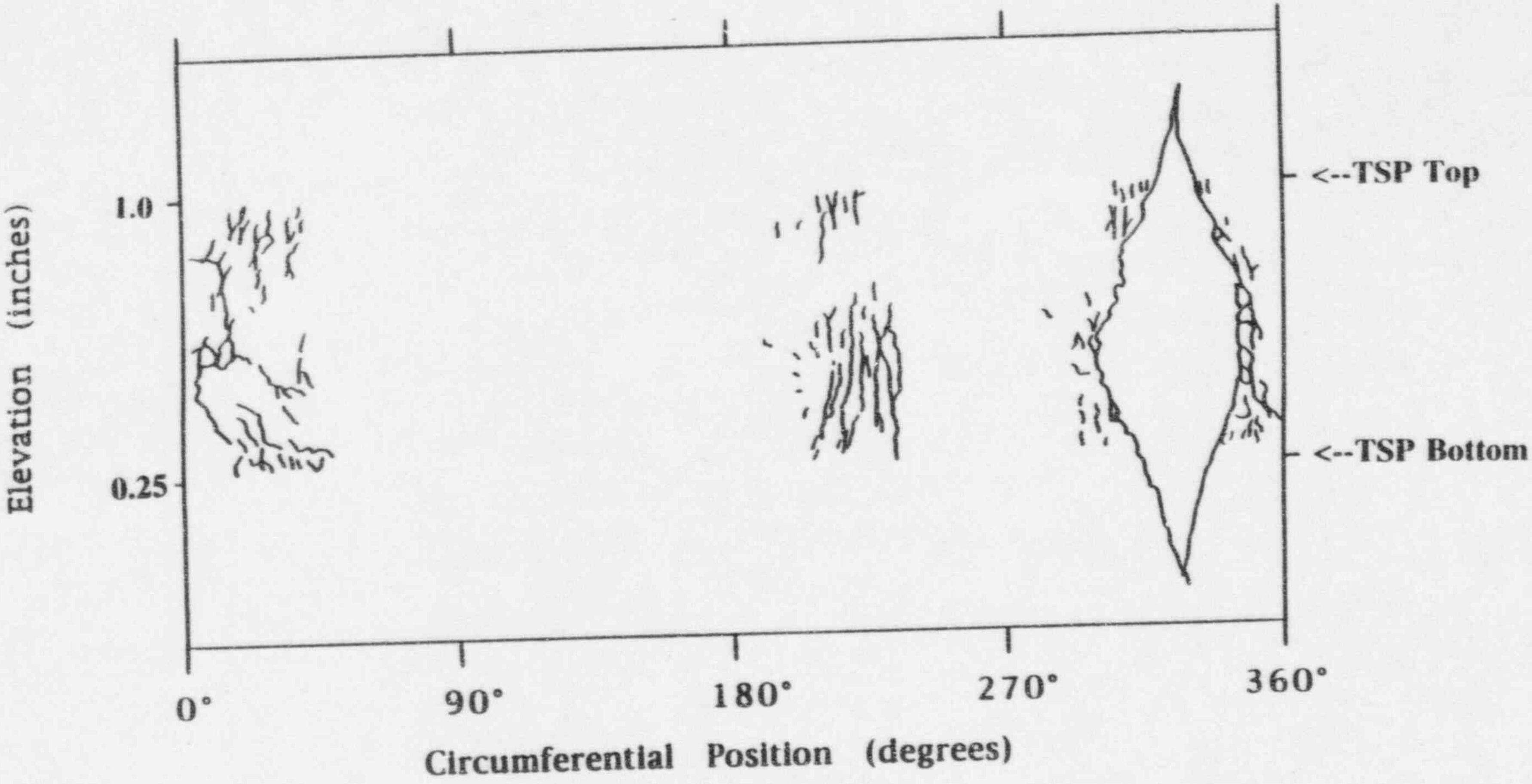


Figure 3-3 Sketch of the OD surface crack distribution found at the first tube support plate (TSP1) of Tube R11C51. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

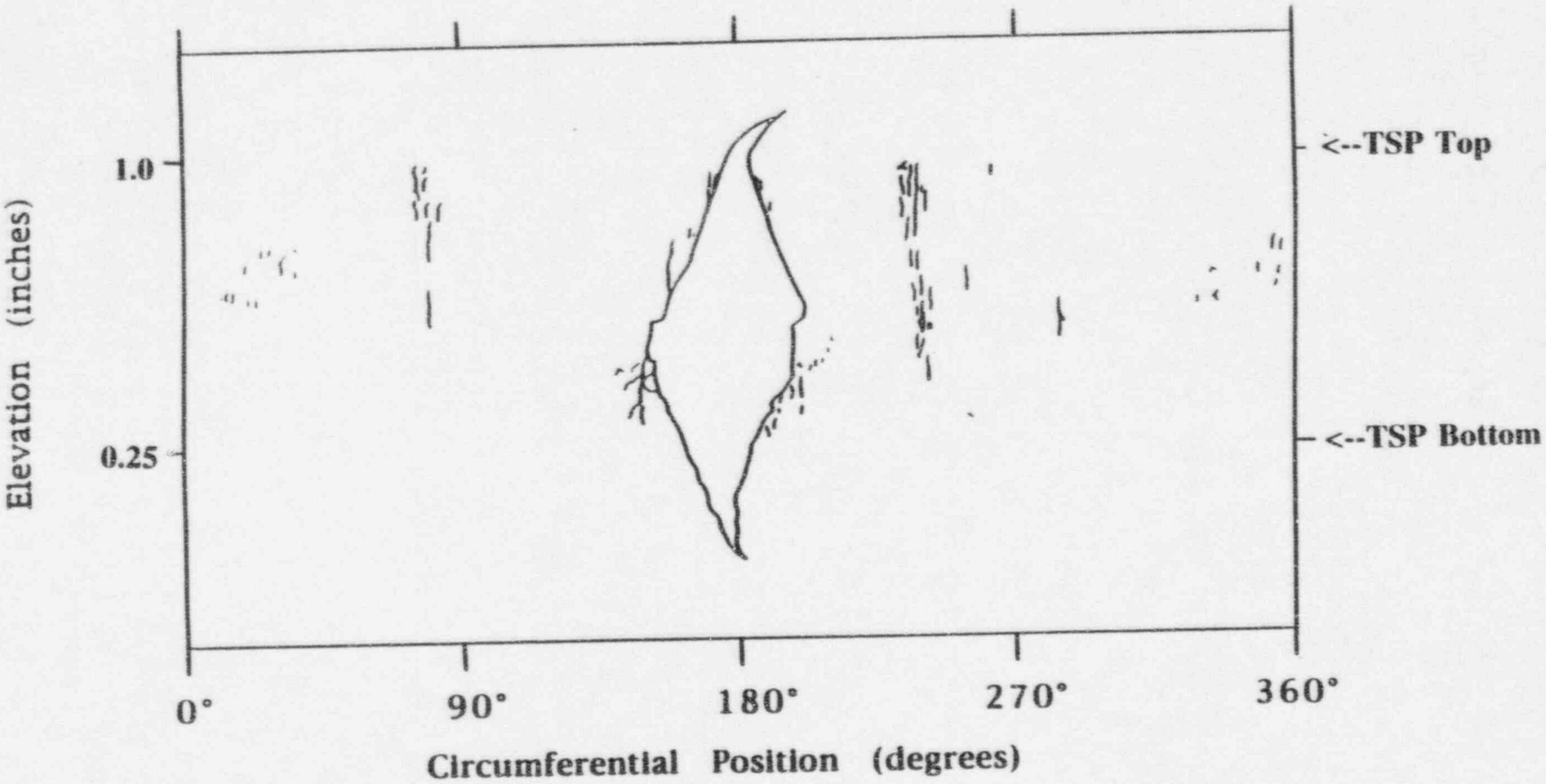


Figure 3-4 Sketch of the OD surface crack distribution found at the second tube support plate (TSP2) of Tube R11C61. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

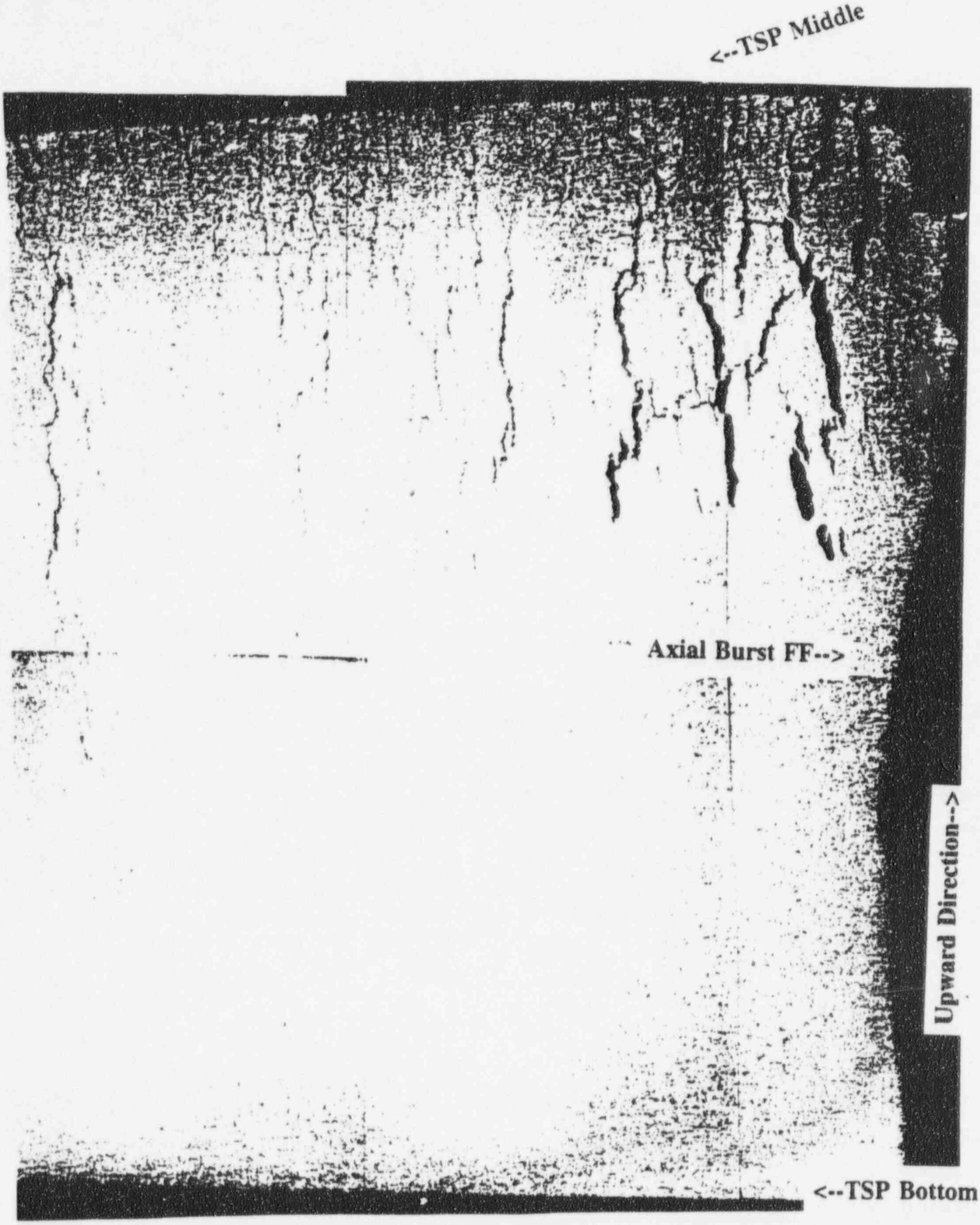


Figure 3-5 OD radial metallography showing intergranular cellular corrosion (ICC) present along with the more dominant axial intergranular stress corrosion cracking (IGSCC) at the first tube support plate (TSP1) of Tube R9C55. 16X Mag. 10% depth

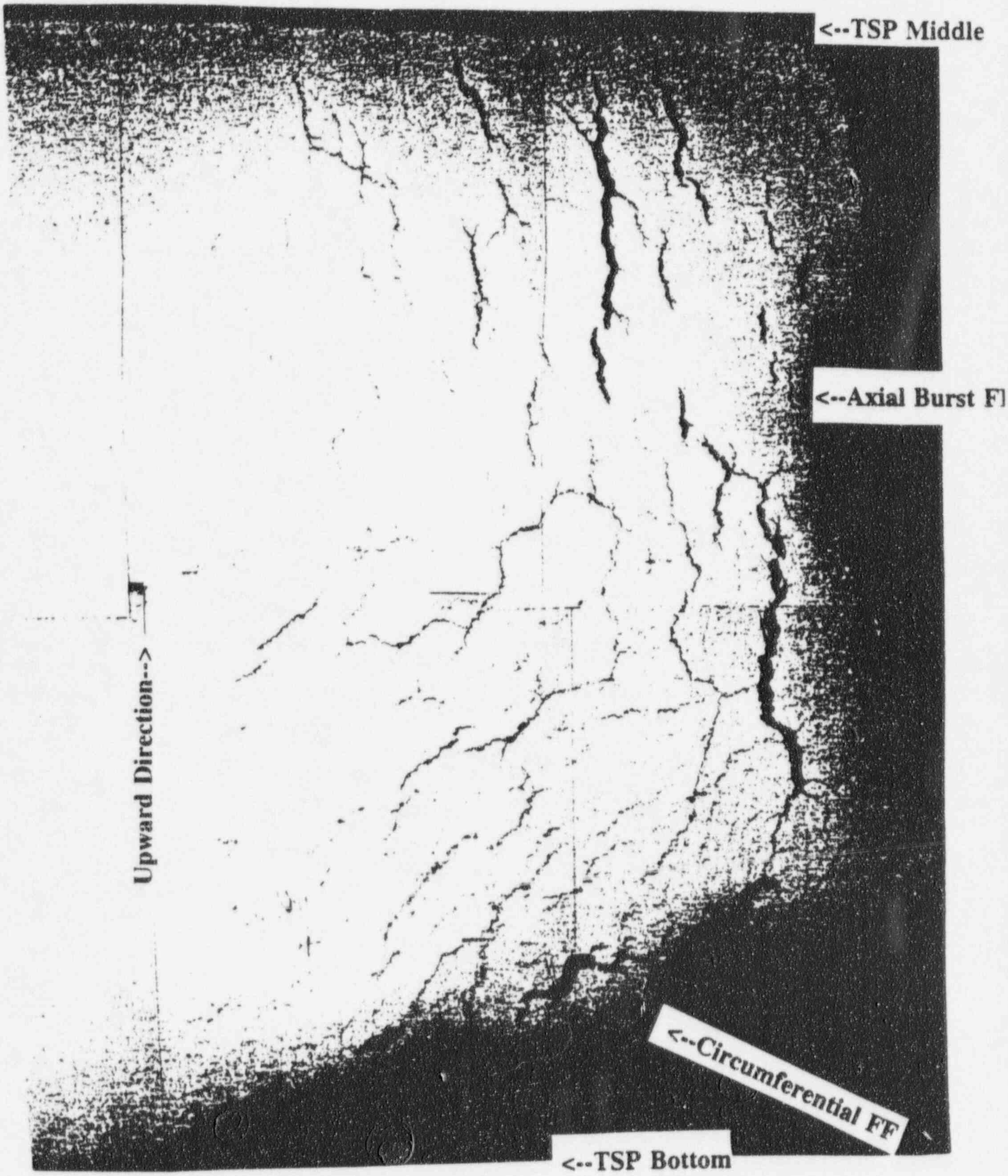


Figure 3-6 OD radial metallography showing intergranular cellular corrosion (ICC) present along with the more dominant axial intergranular stress corrosion cracking (IGSCC) in the middle of the first tube support plate (TSP1) of Tube R11C61 and along with the more dominant circumferential cracking near the bottom of the TSP crevice region. 16X Mag. 10% depth

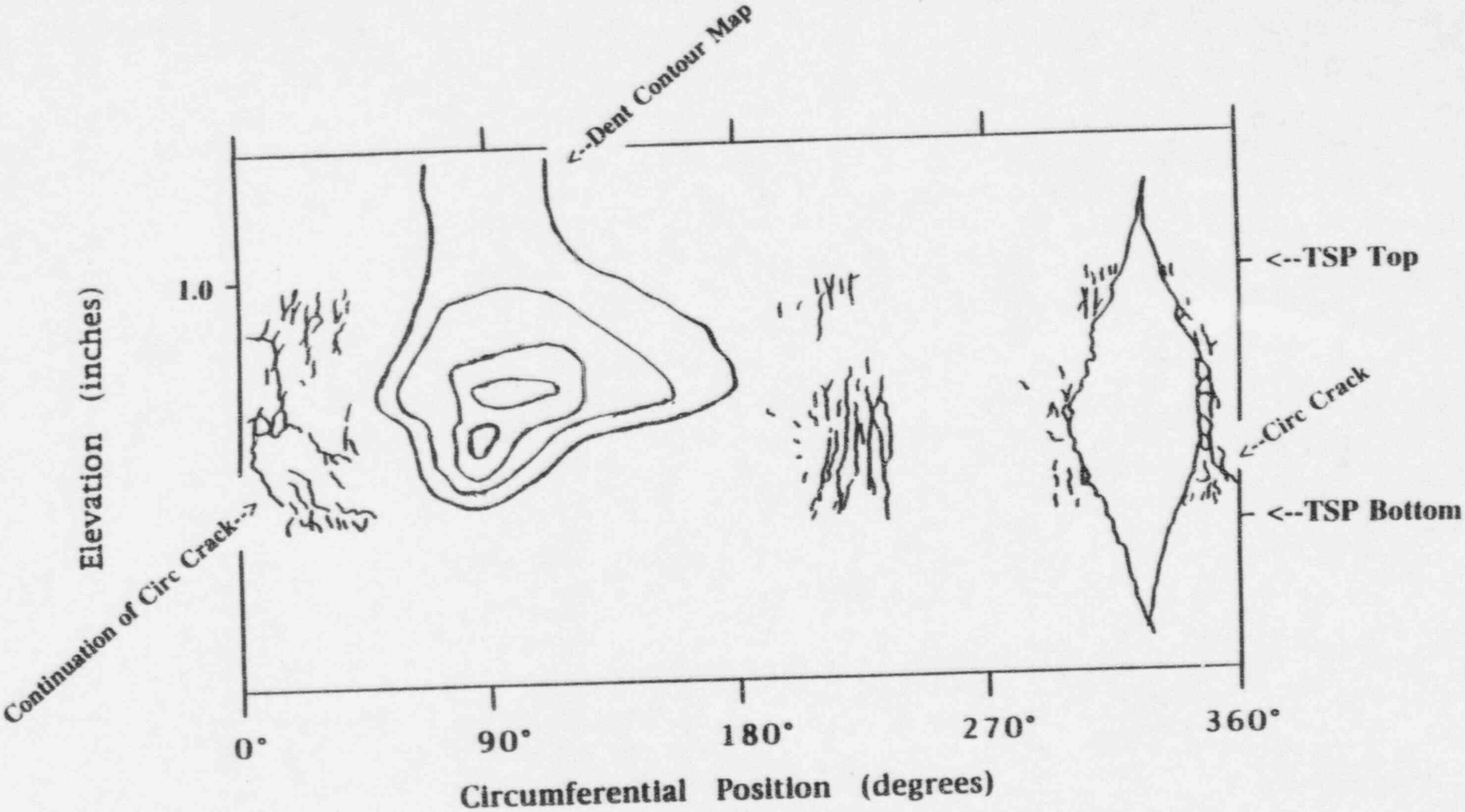


Figure 3-7 Sketch of the OD surface crack distribution found at the first tube support plate (TSP1) of Tube R11C61. Also shown is a contour map of the dent showing its location relative to the observed corrosion.

Figure 3-8
Sequoyah R9C55, TSP 1; Axial ODSCC Cracks

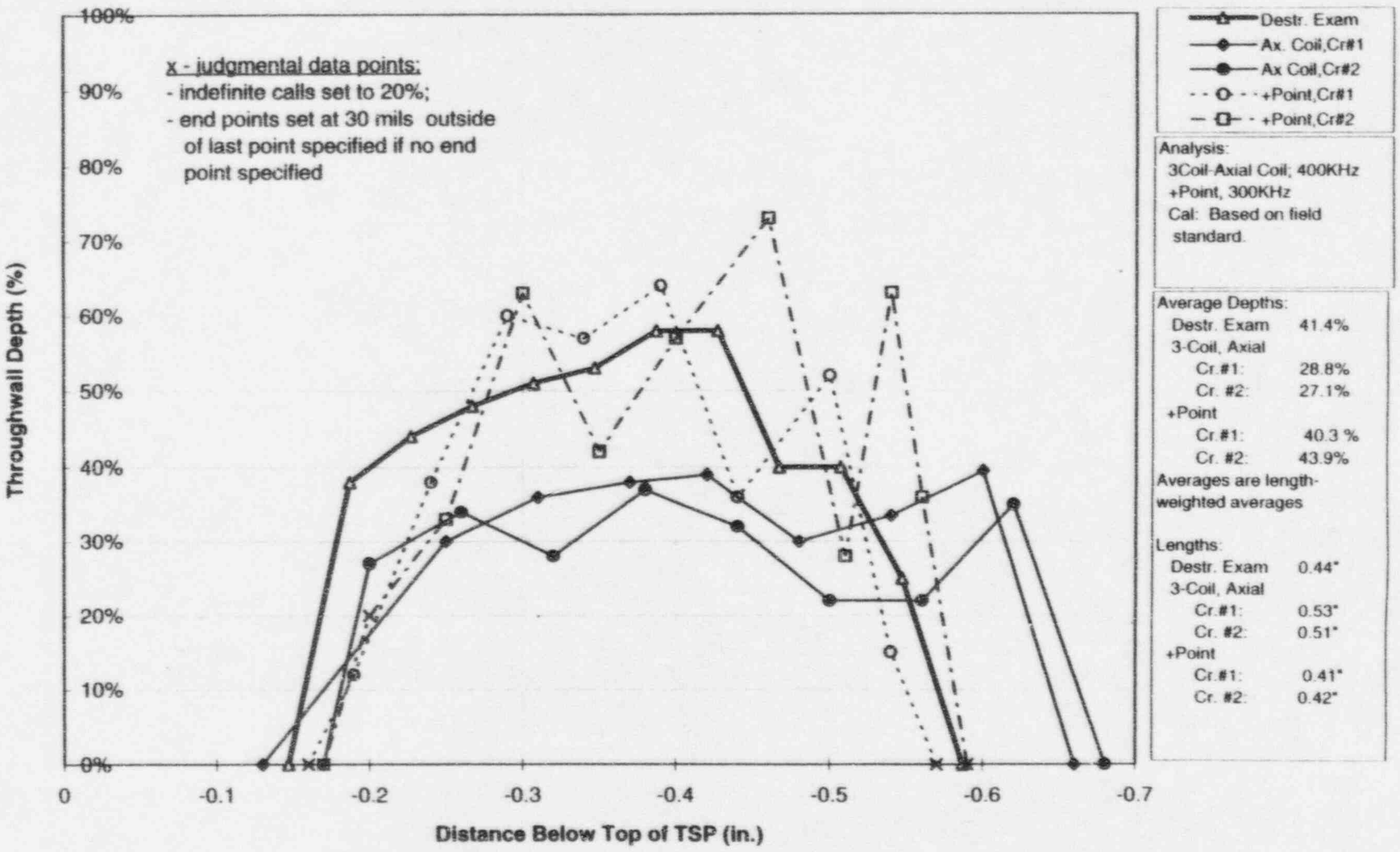
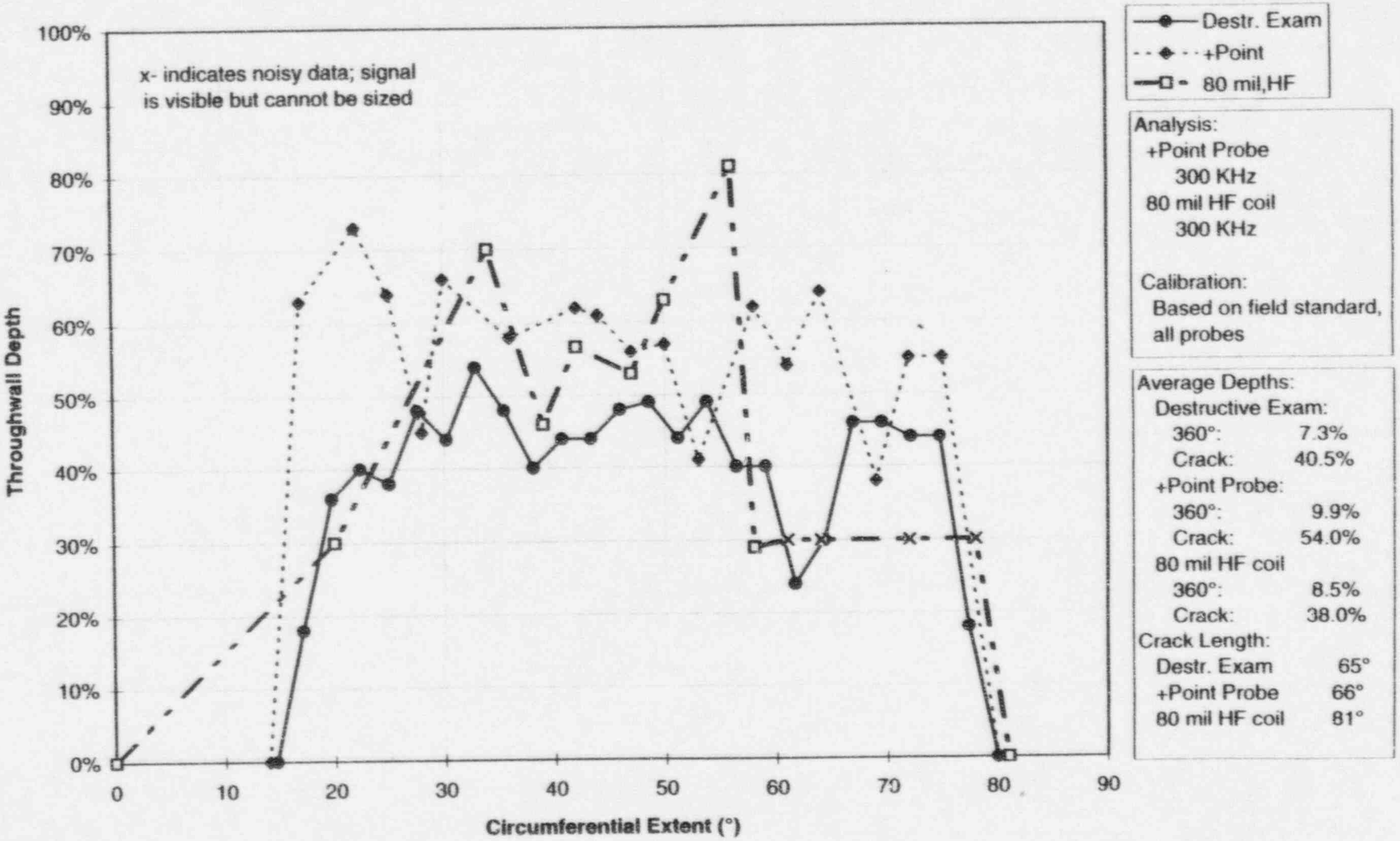


Figure 3-9
Sequoyah R11C61 - 1H; Circumferential Crack Profile Evaluation

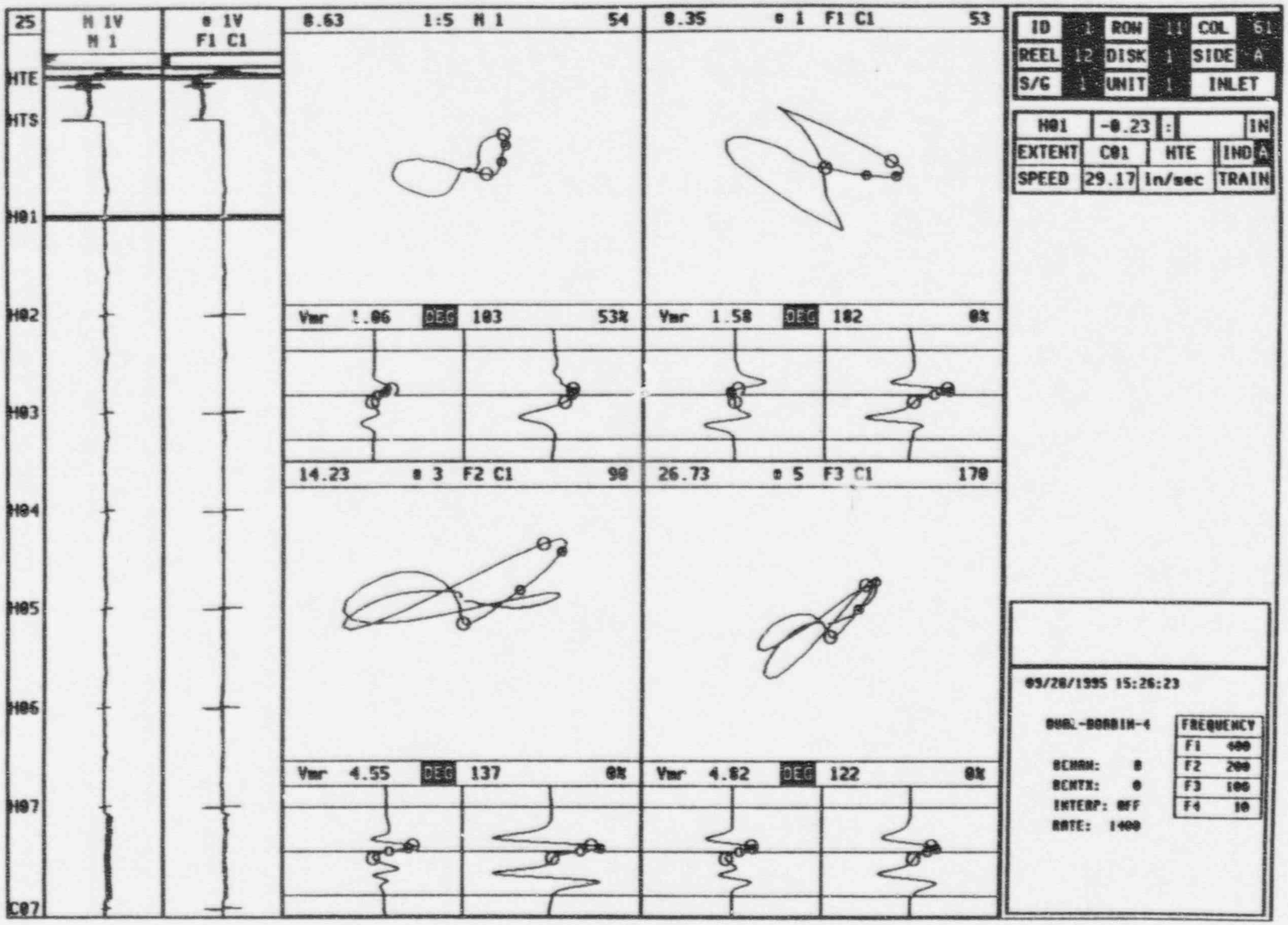


Analysis:
+Point Probe
300 KHz
80 mil HF coil
300 KHz

Calibration:
Based on field standard, all probes

Average Depths:

Destructive Exam:	
360°:	7.3%
Crack:	40.5%
+Point Probe:	
360°:	9.9%
Crack:	54.0%
80 mil HF coil	
360°:	8.5%
Crack:	38.0%
Crack Length:	
Destr. Exam	65°
+Point Probe	66°
80 mil HF coil	81°



ID 1 ROW 11 COL 61
REEL 12 DISK 1 SIDE A
S/G 1 UNIT 1 INLET

H01 -0.23 : IN
EXTENT C01 HTE IND A
SPEED 29.17 in/sec TRAIN

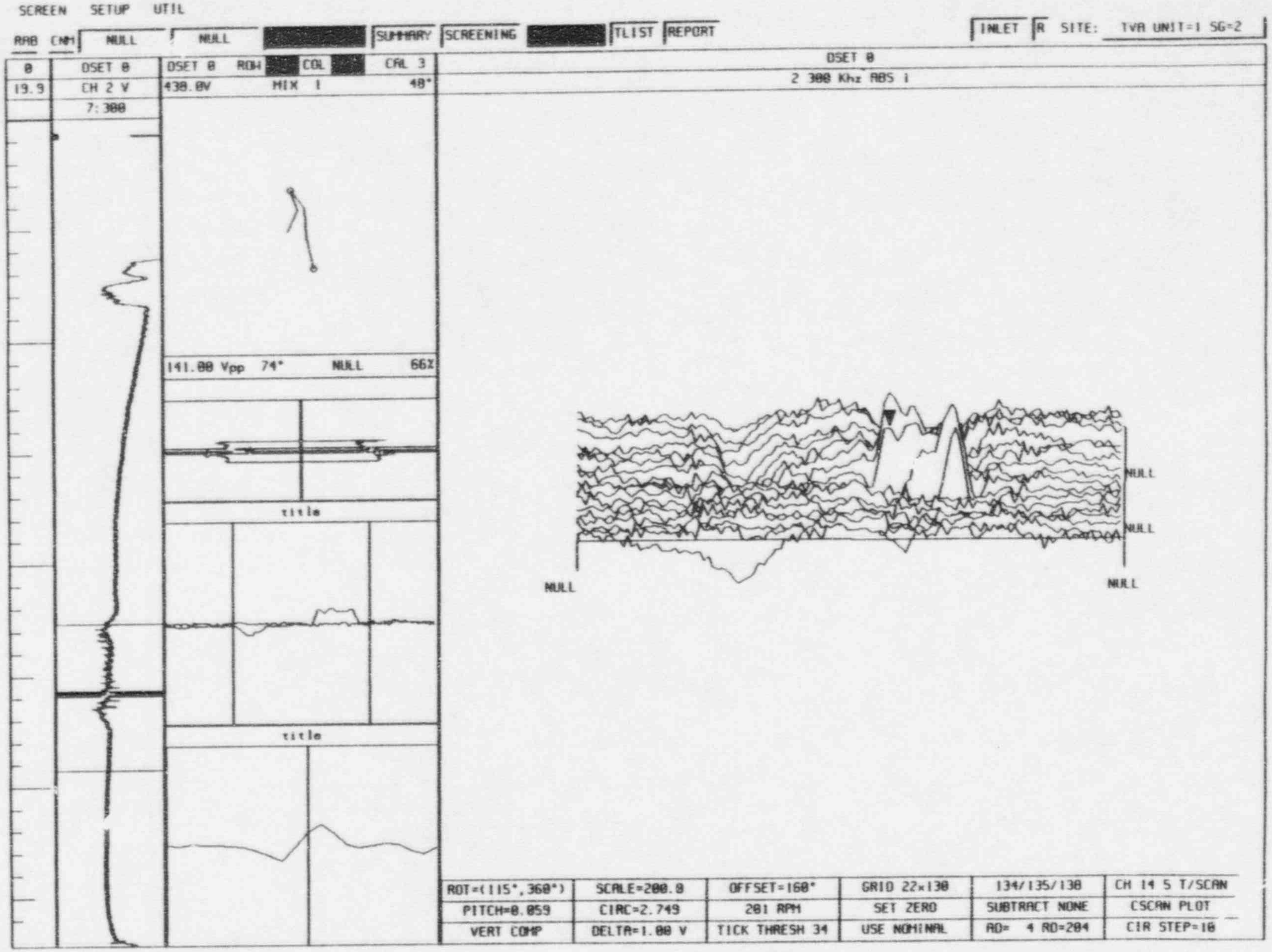
09/20/1995 15:26:23

DUAL-BOBBIN-4

BCHAN: 0
BCNTX: 0
INTERP: OFF
RATE: 1400

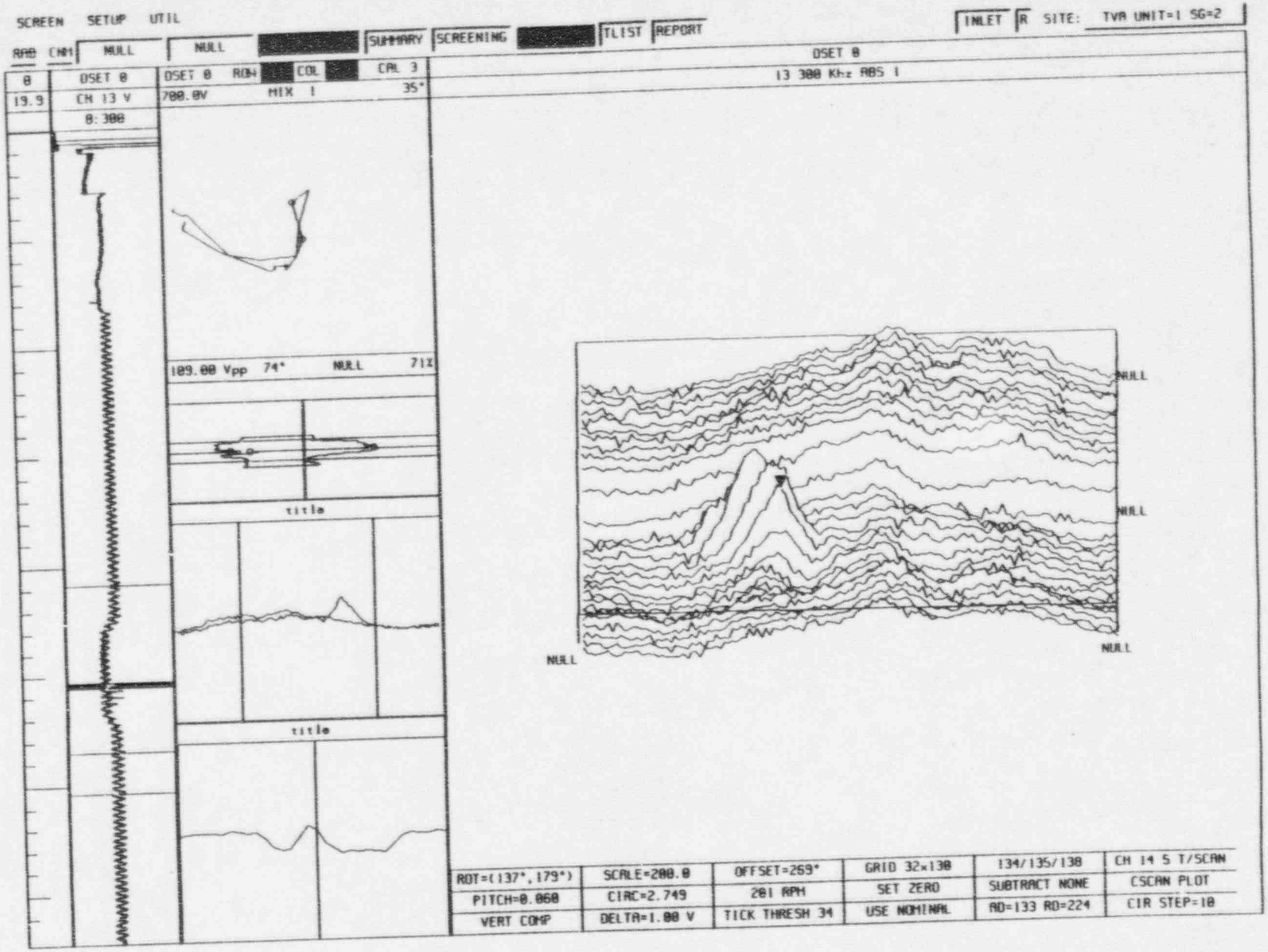
FREQUENCY	
F1	400
F2	200
F3	100
F4	10

Figure 3-10 R11C61-TSP1: Laboratory Reanalysis of Bobbin Field Data.



ROT=(115°,360°)	SCALE=200.0	OFFSET=160°	GRID 22×130	134/135/130	CH 14 5 T/SCAN
PITCH=0.059	CIRC=2.749	201 RPM	SET ZERO	SUBTRACT NONE	CSCAN PLOT
VERT COMP	DELTA=1.00 V	TICK THRESH 34	USE NOMINAL	AD= 4 AD=204	CIR STEP=10

Figure 3-11 R11C61-TSP1: + Point Field Data.



DSET 0
CH 13 V
8:300

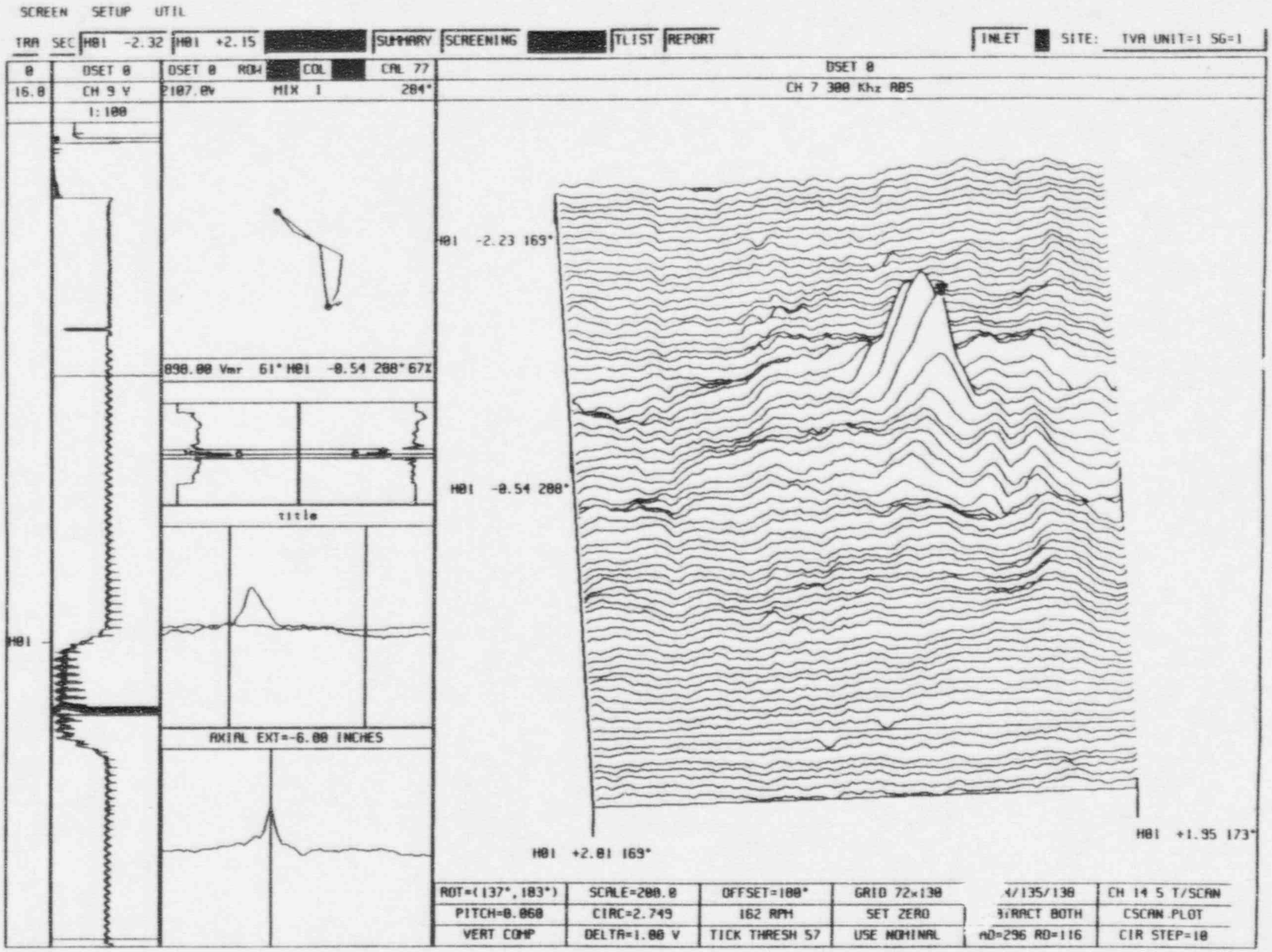
DSET 0
700.0V
MIX 1
35°

109.00 Vpp 74° NULL 71%

DSET 0
13 300 Khz ABS 1

ROT=(137°,179°)	SCALE=200.0	OFFSET=269°	GRID 32x130	134/135/138	CH 14 5 T/SCAN
PITCH=0.060	CIRC=2.749	201 RPM	SET ZERO	SUBTRACT NONE	CSCAN PLOT
VERT COMP	DELTA=1.00 V	TICK THRESH 34	USE NOMINAL	AD=133 RD=224	CIR STEP=10

Figure 3-12 R11C61 - 1H: 80 mil Pancake Coil Field Data



SITE: TVA UNIT=1 SG=1

DSET 0 CH 9 V

DSET 0 ROW COL CAL 77

2107.0v MIX 1 284°

DSET 0 CH 7 300 Khz ABS

890.00 Vmr 61° H01 -0.54 200° 67%

AXIAL EXT=-6.00 INCHES

ROT=(137°,183°) SCALE=200.0 OFFSET=180° GRID 72x130 4/135/130 CH 14 5 T/SCAN

PITCH=0.060 CIRC=2.749 162 RPM SET ZERO RACT BOTH CSCAN PLOT

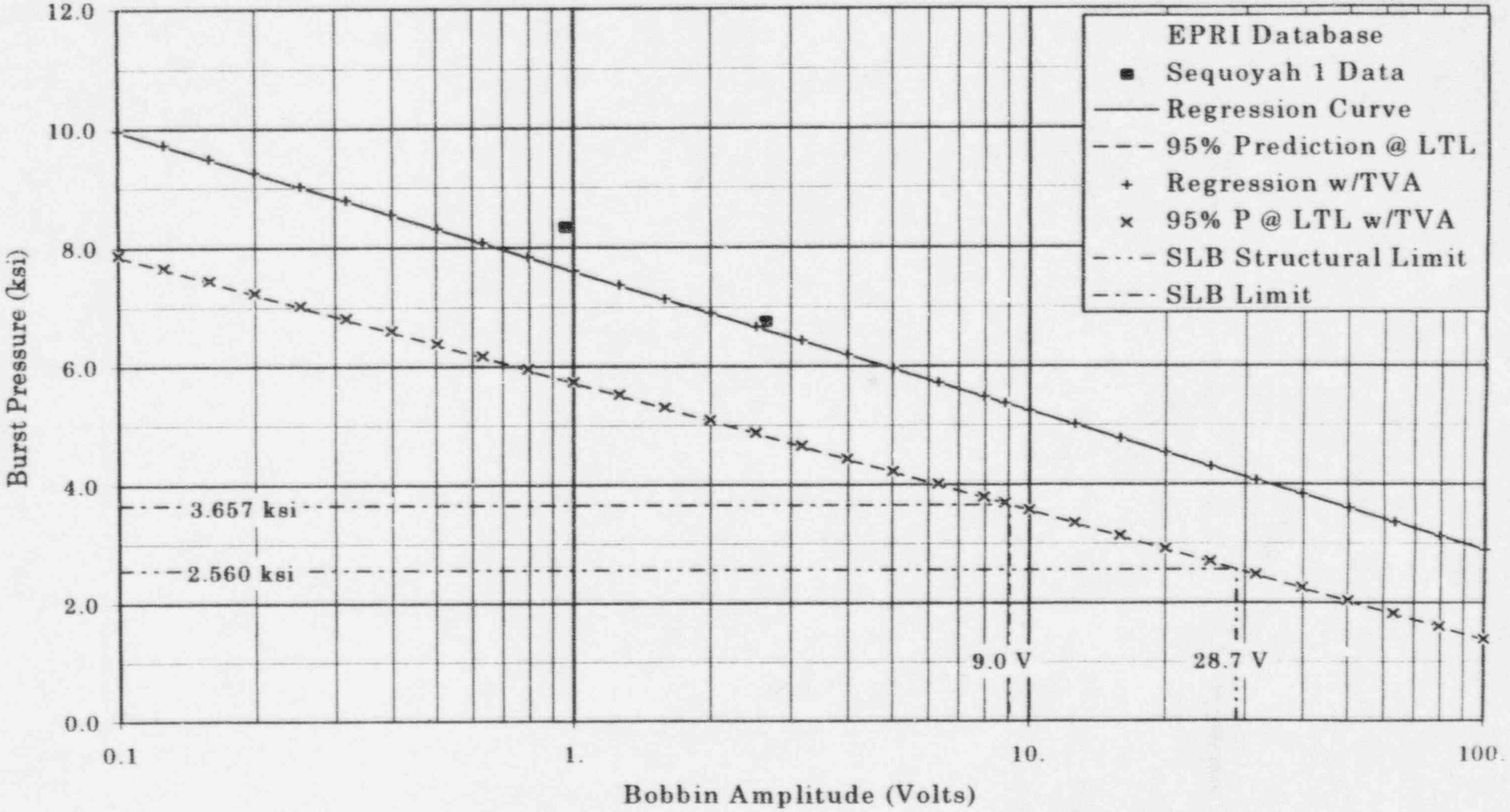
VERT COMP DELTA=1.00 V TICK THRESH 57 USE NOMINAL AD=296 RD=116 CIR STEP=10

Figure 3-13 R11C61-1H: 115 Mil Pancake Coil Field Data.

Figure 3-14

Burst Pressure vs Volts for 7/8" OD Alloy 600 SG Tubes

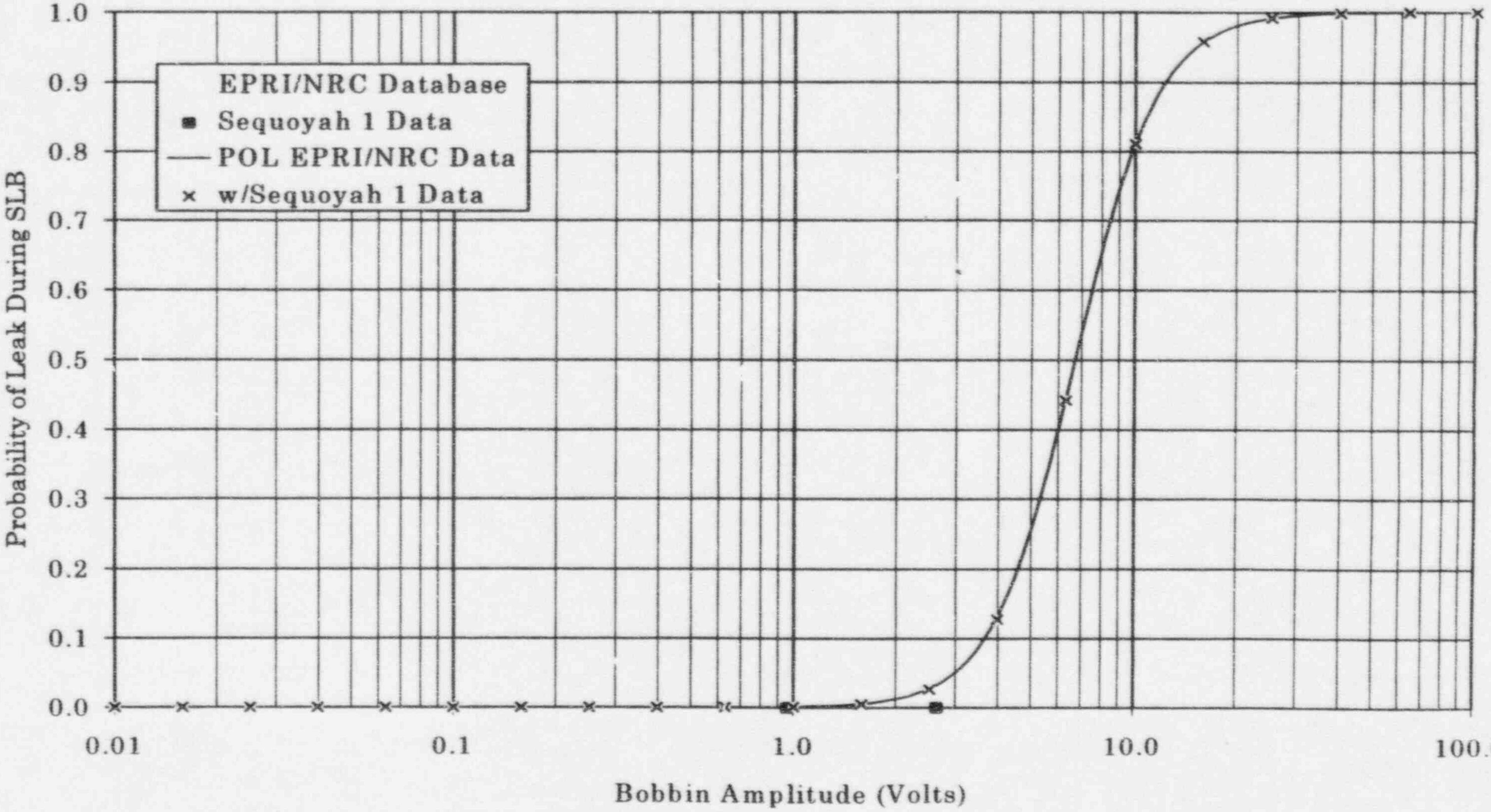
NRC/EPRI Database, Reference σ_f = 68.8 ksi @ 650°F



s:\apc\tva95\cy8_90day.wp5

Figure 3-15

Probability of Leak for 7/8" SG Tubes
Effect of Inclusion of Sequoyah 1 Data



4.0 EOC-7 INSPECTION RESULTS AND VOLTAGE GROWTH RATES

4.1 EOC-7 Inspection Results

In accordance with the Generic Letter 95-05, the inspection of the EOC-7 Sequoyah Unit 1 SG consisted of a complete, 100% EC bobbin probe examination of all hot leg TSP intersections in the tube bundles of all four SGs. A 0.720 inch diameter probe was used for all hot leg TSP indications where APC was applied. Subsequently, RPC examination was performed for all bobbin indications with amplitudes greater than 2 volts. RPC confirmed indications greater than 2 bobbin volts were repaired. In addition, an augmented RPC inspection was performed consistent with the Generic Letter 95-05 requirements. The augmented RPC inspection included all TSP intersections with dent voltages over 5.0 volts in SGs 1 and 2 and a sample in SGs 3 and 4. Furthermore, a sample of dents under 5 volts were also inspected under an expansion of the dent inspection program.

During the RPC examination of dented support plate intersections with the +Point probe, some outside diameter stress corrosion cracking (ODSCC) axial indications were reported which could not be detected by the bobbin probe. All but one of these indications were left in service to establish their growth rates in future outages. A bobbin voltage was assigned to all these indications on the basis of their RPC voltage. An average value of 1.17 was used for the ratio of bobbin voltage to +Point voltage, which was established by examining the voltage data for those TSP intersections where both probe voltages are available. Six ODSCC axial indications were identified in this manner (four in SG-3 and two in SG 4), and they are included in the analyses for leak rate and burst probability.

Only 49 axial TSP ODSCC indications (including the six indications at dented intersections detected with +Point probe) were found in all four steam generators combined in the EOC-7 inspection. Of these, only two indications have a voltage above 2 volts. These two indications plus five other bobbin indications below 2 volts were RPC inspected and confirmed as flaws.

A summary of EC indication statistics for all four SGs is shown on Table 4-1. The table shows the number of field bobbin indications detected during the current (EOC-7) inspection, the number of these field bobbin indications that were RPC inspected, the number of RPC confirmed indications, the number of repaired indications, and the total number of indications in tubes returned to service for Cycle 8 operation. Bobbin voltage distribution for all indications detected during the current inspection is also shown in graphical form in Figure 4-1.

Overall, the combined data for four SGs of Sequoyah-1 show that:

- The total number of indications detected, 49, is a very small fraction of that found in recent inspections at other plants (which varies from several hundreds to several thousands).

- Of the 49 indications in service during Cycle 7 and identified during the EOC-7 inspection, a total of 13 were RPC inspected.

- All indications inspected with RPC were confirmed, of which only two indications had a bobbin voltage above 2 volts.

- Four indications were removed from service due to tube plugging, which included the two RPC-confirmed indications above 2 volts requiring repair for ODSCC. The remaining 45 indications were returned to service for Cycle 8.

- All 49 indications detected were at the hot leg TSP intersections, and all but 6 of these indication were found at the first TSP intersections. Among the 6 indications found above the first TSP, one was found at the second TSP of SG 2, two each at the second TSP of SGs 3 and 4, and a single indication at the third TSP of SG 3. This distribution is consistent with the pattern generally found in other plants, i.e., ODSCCs are found mostly in the first few hot leg TSPs.

Review of Table 4-1 indicates that SG 3 has the largest number of BOC-8 indications (a quantity of 22, with 5 indications above 1.0 volt), thereby it potentially will be the limiting SG at EOC-8.

4.2 Voltage Growth Rates

Out of the 49 indications detected during the EOC-7 inspection, bobbin data from a prior inspection are available only for 43 indications since six indications found with the +Point probe at the dented TSP intersections were not detected during prior inspections. Even the prior bobbin data found are not all from the same inspection, with 23 values coming from either the EOC-5 or an earlier outage, and, consequently, the voltage growth noted occurred over different periods. Therefore, to make the bobbin voltage growth values more consistent they were converted to growth rate per effective full-power year (EFPY) by making adjustments for growth periods. The resulting growth rate distribution is tabulated in Table 4-2. Since there are only 43 indications from all four SGs combined, only the composite growth data is shown.

The NRC guidelines in Generic Letter 95-05 stipulate that a plant-specific growth rate distribution used in SLB leak rate and tube probability analyses to support APC application must contain at least 200 data points that are established using bobbin voltages measured in two consecutive inspections. Since there are only 43 datapoints in the data in Table 4-2, of which only 20 values are based on bobbin voltages from two consecutive inspections, the Sequoyah-1 growth data do not meet the above NRC requirement. In the absence of an acceptable plant-specific growth database, Generic Letter 95-05 requires the use of a bounding growth rate distribution established based on data available from similarly designed and operated plants. Therefore, a generic growth distribution was developed using available growth data for plants with 7/8 inch diameter tubes and applied to the Sequoyah-1 plant.

The generic growth distribution developed and applied for Sequoyah-1 includes growth data for ODSCC indications obtained from twelve recent inspections in plants with 7/8-inch diameter tubes. Only the data relevant to ODSCC indications at TSP intersections are included. Growth data from different plants were expressed as growth rates per EFPY to account for different plant operating periods. The resulting growth rate distributions for the twelve inspections, expressed as cumulative probability distribution, are shown in Table 4-3; they are also plotted in Figure 4-3 . The plant codes used in Table 4-3 and Figure 4-3 are same as those in the EPRI documents cited in References 9.4 and 9.5. All of the bobbin voltage data used in the growth database established have been either initially evaluated or revaluated using the IPC/APC-recommended inspection guidelines employed since 1992. Except for the Plant A-1 Cycle 11 data below about 0.6 volts, all growth distributions found are within a narrow band.

Using the growth database thus established, an upper bound growth distribution for plants with 7/8 inch diameter tubes was obtained so as to envelope the twelve growth rate distributions considered; it is shown in Table 4-3 as well as plotted in Figure 4-3. For growth rates up to 0.6 volt, the upper bound distribution selected follows the higher growth rates observed for Cycle 11 of Plant A-1. Between 0.6 volt and 1 volt, growth rates for Cycle 9 of Plant A-2 are constant and they are bounding. However, since there are only 4 datapoints between 0.6 volt and 1.5 volt for Cycle 9 of Plant A-2, and a larger number of datapoints would have yielded a cumulative probability distribution function (CPDF) that is a monotonically increasing function of growth rate, the upper bound distribution was defined such that it increases smoothly in the 0.6 volt to 1.5 volt range. The upper bound growth distribution thus obtained is compared with the CPDF distribution for limited growth data available for Sequoyah-1 in Figure 4-2, and it is noted that clearly the former is substantially more conservative. The CPDF values defining the upper bound distribution are utilized to predict EOC-8 voltage distributions that are used in SLB leak rate and tube burst analyses.

4.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 8 voltage projections in this report are documented in References 9.2 and 9.3 and they are consistent with NRC GL 95-05 (Reference 9.1). The probe wear uncertainty has a standard deviation of 7.0% about a mean of zero and has a cutoff at 15% based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses used to predict the EOC-8 voltage distributions.

Table 4 - 1
Sequoyah Unit 1 1995 EOC-7
Summary of Inspection and Repair For Tubes in Service During Cycle 7

Voltage Bin	Steam Generator 1					Steam Generator 2				
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.3	2	0	0	0	2	0	0	0	0	0
0.4	2	0	0	0	2	0	0	0	0	0
0.5	1	0	0	0	1	1	0	0	0	1
0.6	0	0	0	0	0	4	0	0	0	4
0.7	1	1	1	1	0	0	0	0	0	0
0.8	0	0	0	0	0	1	0	0	0	1
0.9	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	1	0	0	0	0	0
1.1	1	0	0	0	1	0	0	0	0	0
1.3	1	0	0	0	1	0	0	0	0	0
1.4	0	0	0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0	0	0
1.6	0	0	0	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
2.6	0	0	0	0	0	0	0	0	0	0
2.7	1	1	1	1	0	0	0	0	0	0
Total	10	3	3	2	8	6	0	0	0	6
> 1V	3	1	1	1	2	0	0	0	0	0
> 2V	1	1	1	1	0	0	0	0	0	0

Voltage Bin	Steam Generator 3					Steam Generator 4				
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.3	1	0	0	0	1	0	0	0	0	0
0.4	0	0	0	0	0	1	0	0	0	1
0.5	1	0	0	0	1	1	1	1	0	1
0.6	3	0	0	0	3	0	0	0	0	0
0.7	2	0	0	0	2	0	0	0	0	0
0.8	5	1	1	0	5	1	0	0	0	1
0.9	1	1	1	0	1	0	0	0	0	0
1	4	1	1	0	4	0	0	0	0	0
1.1	0	0	0	0	0	2	1	1	0	2
1.3	0	0	0	0	0	0	0	0	0	0
1.4	2	0	0	0	2	0	0	0	0	0
1.5	1	0	0	0	1	1	1	1	0	1
1.6	1	1	1	1	0	2	1	1	0	2
1.7	2	1	1	0	2	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	1
2.6	1	1	1	1	0	0	0	0	0	0
2.7	0	0	0	0	0	0	0	0	0	0
Total	24	6	6	2	22	9	4	4	0	9
> 1V	7	3	3	2	5	6	3	3	0	6
> 2V	1	1	1	1	0	0	0	0	0	0

Table 4 - 2
Sequoyah Unit-1 Signal Growth statistics Cumulative Probability Distribution Function on an EFPY Basis

Voltage Bin	Cumulative Data from All SGs[#]	
	No. of Indications	CPDF
-0.5	0	0
-0.4	1	0.02326
-0.3	0	0.02326
-0.2	1	0.04651
-0.1	9	0.25581
0.0	16	0.62791
0.1	10	0.86047
0.2	3	0.93023
0.3	2	0.97674
0.4	0	0.97674
0.5	0	0.97674
0.6	0	0.97674
0.7	0	0.97674
0.8	1	1
0.9	0	1
1.0	0	1
Total	43	

[#] Not all growth values are based on bobbin voltages from consecutive inspections.

Table 4 - 3 (Sheet 1 of 2)
Data Utilized to Establish an Upper Bound Envelope for Growth Rates for 7/8" Dia. Tubes Cumulative Probability Distributions on an EFPY basis (Combined Data for All SGs in the Plant)

Voltage Bin	Plant A-1 Cycle 11 ('91 - '92)		Plant A-1 Cycle 12 ('92 - '94)		Plant A-1 Cycle 13 ('94 - '95)		Plant A-2 Cycle 9 ('92 - '93)		Plant A-2 Cycle 10 ('93 - '95)		Plant D-1 Cycle 12 ('90 - '92)		7/8" Dia Tubes Growth Rate Upper Bound Envelope
	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	
-0.9	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.8	0	0	0	0	0	0	1	0.006	0	0	0	0	0
-0.7	0	0	0	0	0	0	0	0.006	0	0	0	0	0
-0.6	0	0	2	0.001	0	0	0	0.006	0	0	0	0	0
-0.5	0	0	5	0.004	0	0	0	0.006	0	0	0	0	0
-0.4	0	0	10	0.010	2	0.001	1	0.012	0	0	0	0	0
-0.3	1	0.001	36	0.031	12	0.005	0	0.012	1	0.005	2	0.010	0
-0.2	2	0.002	69	0.072	39	0.021	5	0.041	3	0.020	4	0.030	0
-0.1	13	0.013	200	0.191	175	0.089	14	0.124	20	0.122	17	0.114	0
0	105	0.095	593	0.544	588	0.317	38	0.349	69	0.472	61	0.418	0.09535
0.1	312	0.341	490	0.835	998	0.706	55	0.675	84	0.898	79	0.811	0.34121
0.2	337	0.607	172	0.937	472	0.889	24	0.817	14	0.970	30	0.960	0.60678
0.3	263	0.814	61	0.973	191	0.963	17	0.917	4	0.990	5	0.985	0.81403
0.4	129	0.916	23	0.987	49	0.982	5	0.947	1	0.995	3	1.0	0.91568
0.5	45	0.951	14	0.995	22	0.991	5	0.976	0	0.995			0.95114
0.6	33	0.977	3	0.997	10	0.995	1	0.982	0	0.995			0.97715
0.7	11	0.986	2	0.998	4	0.996	0	0.982	0	0.995			0.98582
0.8	7	0.991	2	0.999	1	0.997	0	0.982	0	0.995			0.99133
0.9	4	0.994	1	1.0	0	0.997	0	0.982	0	0.995			0.99250
1	2	0.996			0	0.997	0	0.982	0	0.995			0.99400
1.1	1	0.997			3	0.998	1	0.988	0	0.995			0.99500
1.2	2	0.998			0	0.998	1	0.994	1	1.0			0.99600
1.3	0	0.998			0	0.998	0	0.994					0.99700
1.4	1	0.999			1	0.998	0	0.994					0.99800
1.5	0	0.999			0	0.998	1	1.0					0.99840
1.6	1	1.0			1	0.999							0.99883
1.7					0	0.999							0.99883
1.8					0	0.999							0.99883
1.9					0	0.999							0.99883
2					1	0.999							0.99922
2.1					0	0.999							0.99922
2.2					0	0.999							0.99922
2.3					1	0.9996							0.99961
2.4					0	0.9996							0.99961
2.5					0	0.9996							0.99961
2.6					0	0.9996							0.99961
2.7					0	0.9996							0.99961
2.8					0	0.9996							0.99961
2.9					0	0.9996							0.99961
3					0	0.9996							0.99961
3.1					0	0.9996							0.99961
3.9					1	1.0							1.0
Total	1269		1683		2571		169		197		201		

Table 4 - 3 (Sheet 2 of 2)
Data Utilized to Establish an Upper Bound Envelope for Growth Rates for 7/8" Dia. Tubes
Cumulative Probability Distributions on an EFPY basis
(Combined Data for All SGs in the Plant)

Voltage Bin	Plant D-1 Cycle 13 ('92 - '94)		Plant D-1 Cycle 14 ('94 - '95)		Plant F Cycle 19 ('93 - '94)		Plant F Cycle 20 ('94 - '95)		Plant P-1 Cycle 9 ('91 - '93)		Plant P-1 Cycle 10 ('93 - '95)		7/8" Dia Tubes Growth Rate
	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	No. of Indn.	CPDF	Upper Bound Envelope
-0.9	0	0	0	0	0	0	1	0.001	0	0	0	0	0
-0.8	0	0	0	0	1	0.002	1	0.003	0	0	0	0	0
-0.7	0	0	0	0	2	0.005	1	0.004	0	0	1	0.001	0
-0.6	0	0	0	0	1	0.007	2	0.007	0	0	0	0.001	0
-0.5	0	0	0	0	3	0.012	3	0.011	0	0	1	0.002	0
-0.4	0	0	0	0	11	0.031	3	0.015	0	0	3	0.005	0
-0.3	0	0	2	0.003	9	0.047	11	0.031	10	0.009	3	0.007	0
-0.2	9	0.018	3	0.008	38	0.113	33	0.077	41	0.045	21	0.027	0
-0.1	34	0.084	23	0.047	95	0.277	98	0.214	92	0.127	90	0.109	0
0	203	0.479	200	0.382	153	0.542	160	0.438	259	0.357	351	0.432	0.0954
0.1	212	0.891	257	0.812	127	0.763	198	0.716	342	0.661	434	0.830	0.3412
0.2	49	0.986	80	0.946	69	0.882	117	0.880	198	0.837	135	0.954	0.6068
0.3	6	0.998	23	0.985	31	0.936	35	0.929	94	0.921	40	0.991	0.8140
0.4	1	1.0	3	0.990	20	0.971	22	0.959	44	0.960	7	0.997	0.9157
0.5			4	0.997	10	0.988	15	0.980	20	0.978	3	1.0	0.9511
0.6			1	0.998	3	0.993	8	0.992	11	0.988			0.9771
0.7			1	1.0	2	0.997	4	0.997	11	0.997			0.9858
0.8					1	0.998	0	0.997	1	0.998			0.9913
0.9					0	0.998	0	0.997	2	1.0			0.9925
1					0	0.998	1	0.999					0.9540
1.1					0	0.998	1	1.0					0.9950
1.2					0	0.998							0.9960
1.3					0	0.998							0.9970
1.4					1	1.0							0.9980
1.5													0.9984
1.6													0.9988
1.7													0.9988
1.8													0.9988
1.9													0.9988
2													0.9992
2.1													0.9992
2.2													0.9992
2.3													0.9996
2.4													0.9996
2.5													0.9996
2.6													0.9996
2.7													0.9996
2.8													0.9996
2.9													0.9996
3													0.9996
3.1													0.9996
3.9													1
Total	514		597		577		714		1125		1089		

Figure 4 - 1
Sequoyah Unit -1 October 1995
Distributions of Actual Bobbin Voltage
(Six Indications at Dented Intersections Detected by +Point Probe are Included)

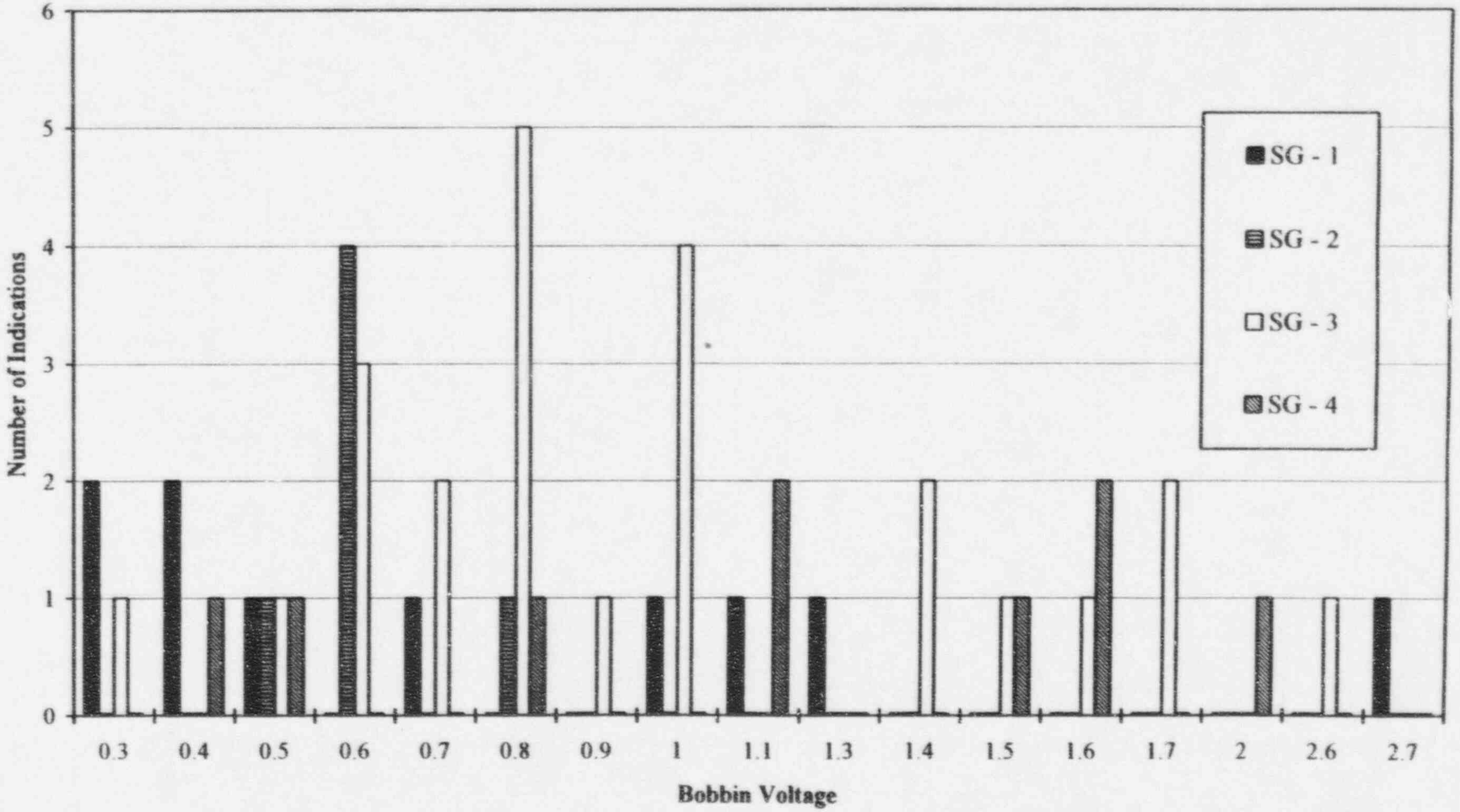


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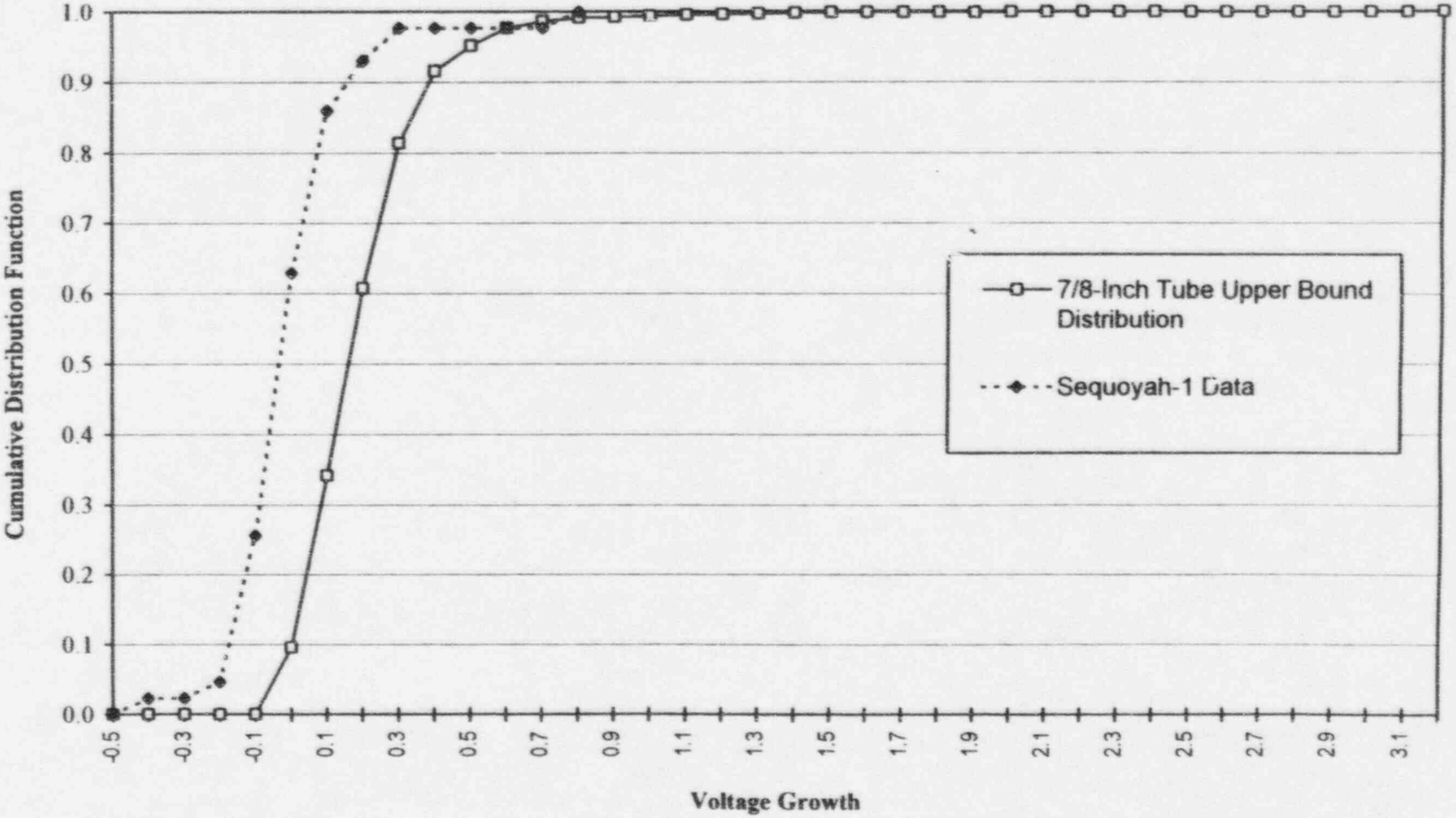
Figure 4 - 2
Comparison of Sequoyah-1 Growth Data with an Upper Bound Distribution for 7/8" Dia. Tubes Used in Analysis
Cumulative Probability Distributions on an EFPY Basis
Composite of All Four Steam Generators

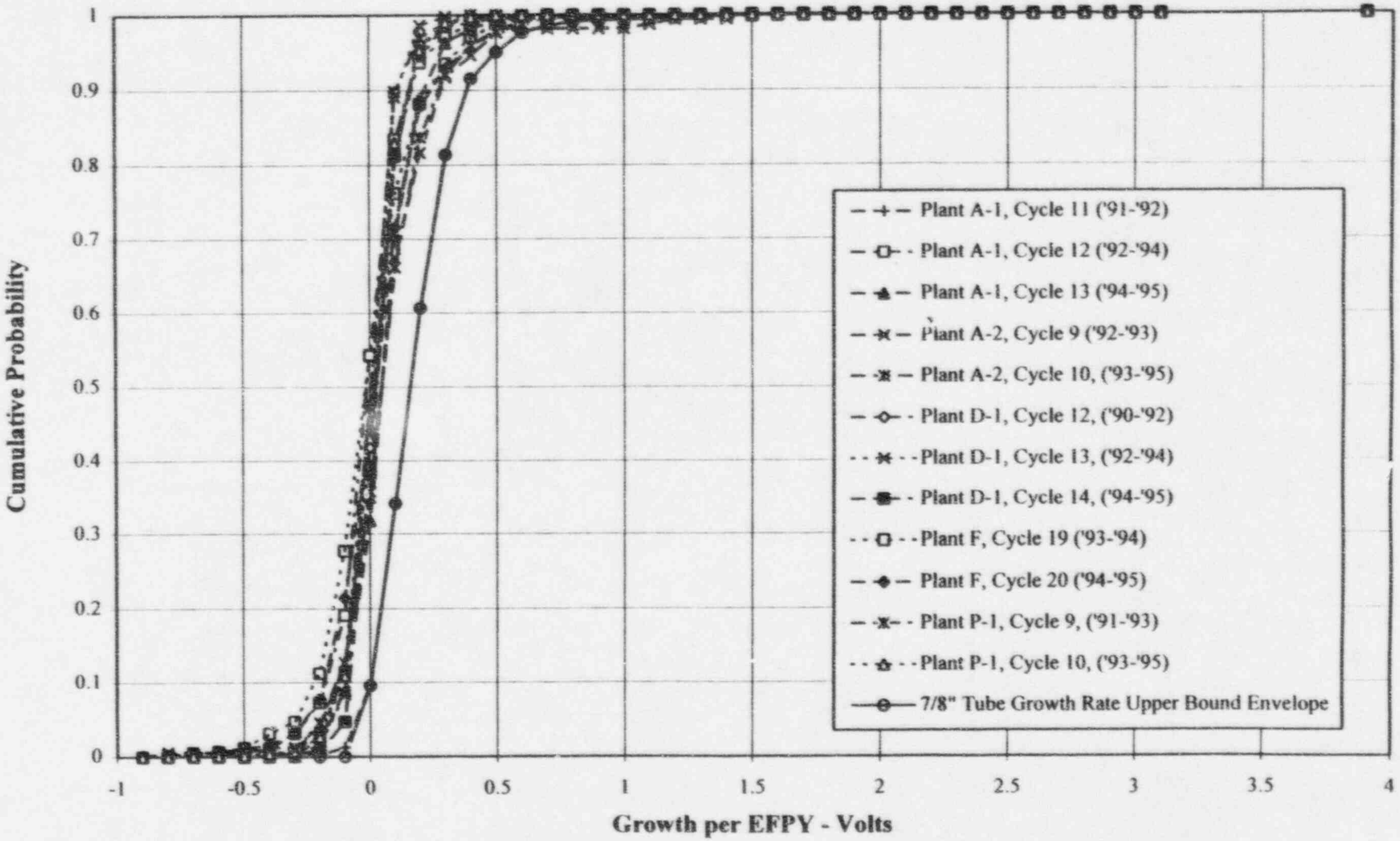


GROWTH XLSFigure 4-2

Figure 4 - 3

Upper Bound Envelope for Growth Rates in Plants with 7/8" Diameter Tubes

Cumulative Probability Distribution on an EFPY basis



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5.0 DATA BASE APPLIED FOR ARC CORRELATIONS

The database used for the ARC correlations applied in the analyses of this report are consistent with those used in the initial IPC submittal for Sequoyah-1 (Reference 9.2). The burst pressure correlation used is based on the EPRI recommended database described in Reference 9.4 as approved by the NRC in GL 95-05. Per NRC requests, this database has been updated to include more recent pulled tube data from plants P-1 and A-2.

For the SLB leak rate correlation, the NRC recommends that Model Boiler specimen 542-4 and Plant J-1 pulled tube R8C74, TSP1 be included in the database. This database is referred to as the NRC database and is applied for the leak rate analyses of this report. As noted in Section 6, the leak rate data does not satisfy statistical requirements for a voltage dependent leak rate correlation.

Two hot leg tube segments removed from SG 1 (Tube R9C55, Tube R11C61), per GL 95-05 requirement, were examined at the Westinghouse Science and Technology center. Results from tube leak test, burst test and destructive examinations are summarized here in Section 3. The pulled tube exam results were also evaluated for application to the EPRI database for ARC application, and it was concluded that inclusion of this Sequoyah-1 data does not significantly affect the existing burst pressure and probability of leak correlations.

6.0 SLB ANALYSIS METHODS

Monte Carlo analyses are used to predict the EOC-8 voltage distributions and to calculate the SLB leak rates and tube burst probabilities for both the actual EOC-7 voltage distribution and the predicted EOC-8 voltage distribution. These methods are consistent with those described in the generic methods report of WCAP-14277 (Reference 9.3) and the Sequoyah-specific report of WCAP-13990 (Reference 9.2).

Based on the NRC recommended leak rate database, the leak rate data do not satisfy the requirement for applying the SLB leak rate versus bobbin voltage correlation. The NRC requirement is that the p value obtained from the regression for the slope parameter be less than or equal to 5%. For the NRC recommended data, the p value is about 6.5% and the leak rate versus voltage correlation is not applied. The SLB leak rate correlation applied is based on an average of all leak rate data independent of voltage. The analysis methods for applying this leak rate model are given in Section 4.6 of WCAP-14277 (Reference 9.3). A Monte Carlo analysis is applied to account for parameter uncertainties even though the leak rate is independent of voltage. This method of leak rate analysis is similar to that of draft NUREG-1477 except for the uncertainty treatment.

7.0 BOBBIN VOLTAGE DISTRIBUTIONS

7.1 Probability of Detection (POD)

The number of indications assumed in the analysis to predict tube leak rate and burst probability is obtained by adjusting the number of indications reported, to account for measurement uncertainty and birth of new indications over the projection period. This is accomplished by using a Probability of Detection (POD) factor. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as:

$$N_{Tot\ RTS} = \frac{N_i}{POD} - N_{Repaired} + N_{deplugged},$$

where:

$N_{Tot\ RTS}$ = Number of bobbin indications being returned to service for the next cycle.
N_i = Number of bobbin indications (in tubes in service) reported in the current inspection.
POD = Probability of Detection.
$N_{repaired}$ = Number of N_i which are repaired (plugged) after the last cycle.
$N_{deplugged}$ = Number of previously-plugged indications which are deplugged, after the last cycle and are returned to service in accordance with IPC applicability.

The NRC generic letter (Reference 9.1) requires the application of a constant POD value of 0.6 to define the beginning of cycle (BOC) distribution for the EOC voltage projections, unless an alternate POD is approved by the NRC. There are no deplugged tubes returned to service at Sequoyah-1 BOC-8.

7.2 Calculation of Voltage Distributions

Since a plant-specific growth rate distribution for the Sequoyah-1 steam generators that meets the NRC requirements specified in Generic Letter 95-05 (Reference 9.1) is not yet available, an upper bound growth rate distribution was developed based on growth data for plants similar in design (i.e., 7/8-inch diameter tube plants) and applied to the analyses reported herein for the EOC-8 condition. Details on the manner in which the upper bound growth rate distribution was established, and the distribution represented by cumulative probability distribution function, are presented in Section 4-2.

The estimated Cycle 8 operating period used in the EOC-8 voltage projection calculations is 471.0 EFPD.

7.3 Predicted EOC-8 Voltage Distributions

Using the methodology previously described, analyses were performed to predict the performance of the Sequoyah-1 steam generators at EOC-8, based on the BOC-7 conditions summarized in Table 7-1 and an upper bound growth distribution for 7/8-inch tube shown in Table 4-3 . An upper bound growth distribution based on a generic database was used since a Sequoyah-specific growth distribution that meets the NRC analysis guidelines in GL 95-05 (Reference 9.1) is not yet available. Calculations were carried out using two values of POD.

POD = 0.6, in accordance with the NRC direction of Reference 9.1.

POD = EPRI, a voltage based uncertainty developed by EPRI.

The EPRI developed voltage dependent POD is based on expert opinion and multiple analysts' evaluations for plants with 3/4" diameter tubes. It is of interest to apply the EPRI POD for sensitivity analysis and compare the results for the case with a POD value of 0.6. The BOC-8 APC voltage distributions are summarized on Table 7-1 for POD of 0.6 and for the EPRI POD, which is the order of decreasing detection uncertainty. The EOC-8 predicted APC voltage distributions are summarized on Table 7-2. As anticipated, the limiting steam generator is SG 3 with 38 indications predicted at EOC-8 for a POD value of 0.6. The assumed BOC-8 and predicted EOC-8 bobbin frequency distributions for each steam generator are shown on Figures 7-1 through 7-4 for constant POD value of 0.6 as well as the voltage dependent EPRI POD. The maximum bobbin voltage predicted for EOC-8 is 3.2 volts for POD value of 0.6 and 2.8 volts for the EPRI POD.

Table 7 - 1
Sequoyah Unit 1 1995 Outage
EOC-7 Field Bobbin and Assumed BOC-8 Bobbin Distributions Used in SLB Leak Rate and Tube Burst Analyses

Voltage	Steam Generator 1				Steam Generator 2			
	EOC-7		BOC -8		EOC-7		BOC -8	
Bin	Field Bobbin Indications	Indications Repaired	POD 0.6	POD EPRI	Field Bobbin Indications	Indications Repaired	POD 0.6	POD EPRI
0.3	2	0	3.33	4.65	0	0	0	0
0.4	2	0	3.33	3.70	0	0	0	0
0.5	1	0	1.67	1.71	1	0	1.67	1.71
0.6	0	0	0	0	4	0	6.67	6.32
0.7	1	1	0.67	0.47	0	0	0	0
0.8	0	0	0	0	1	0	1.67	1.37
0.9	0	0	0	0	0	0	0	0
1	1	0	1.67	1.23	0	0	0	0
1.1	1	0	1.67	1.18	0	0	0	0
1.3	1	0	1.67	1.10	0	0	0	0
1.4	0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0
1.6	0	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
2.6	0	0	0	0	0	0	0	0
2.7	1	1	0.67	0.00	0	0	0	0
Total	10	2	14.67	14.05	6	0	10	9.40
> 1V	3	1	4	2.29	0	0	0	0
> 2V	1	1	0.67	0.00	0	0	0	0

Voltage	Steam Generator 3				Steam Generator 4			
	EOC-7		BOC -8		EOC-7		BOC -8	
Bin	Field Bobbin Indications	Indications Repaired	POD 0.6	POD EPRI	Field Bobbin Indications	Indications Repaired	POD 0.6	POD EPRI
0.3	1	0	1.67	2.33	0	0	0	0
0.4	0	0	0	0	1	0	1.67	1.85
0.5	1	0	1.67	1.71	1	0	1.67	1.71
0.6	3	0	5.00	4.74	0	0	0	0
0.7	2	0	3.33	2.94	0	0	0	0
0.8	5	0	8.33	6.85	1	0	1.67	1.37
0.9	1	0	1.67	1.28	0	0	0	0
1	4	0	6.67	4.92	0	0	0	0
1.1	0	0	0	0	2	0	3.33	2.37
1.3	0	0	0	0	0	0	0	0
1.4	2	0	3.33	2.16	0	0	0	0
1.5	1	0	1.67	1.07	1	0	1.67	1.07
1.6	1	1	0.67	0.05	2	0	3.33	2.10
1.7	2	0	3.33	2.07	0	0	0	0
2	0	0	0	0	1	0	1.67	1.02
2.6	1	1	0.67	0	0	0	0	0
2.7	0	0	0	0	0	0	0	0
Total	24	2	38	30.12	9	0	15	11.48
> 1V	7	2	9.67	5.36	6	0	10	6.55
> 2V	1	1	0.67	0	0	0	0	0

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Table 7 - 2
Sequoyah Unit-1 October 1995
Voltage Distribution Projection for EOC - 8

Voltage Bin	Steam Generator 1		Steam Generator 1		Steam Generator 3		Steam Generator 4	
	Projected Number of Indications at EOC - 8							
	POD 0.6	EPRI POD	POD 0.6	EPRI POD	POD 0.6	EPRI POD	POD 0.6	EPRI POD
0.2	0.04	0.05	0.00	0.00	0.02	0.03	0.00	0.00
0.3	0.62	0.84	0.00	0.00	0.28	0.38	0.03	0.04
0.4	1.24	1.56	0.05	0.05	0.38	0.52	0.31	0.34
0.5	1.58	1.92	0.49	0.48	0.76	0.89	0.58	0.62
0.6	1.58	1.87	1.28	1.24	1.50	1.55	0.66	0.71
0.7	1.35	1.55	1.69	1.62	2.36	2.26	0.69	0.71
0.8	1.01	1.10	1.79	1.69	3.24	2.93	0.69	0.68
0.9	0.75	0.75	1.60	1.49	3.82	3.31	0.65	0.60
1.0	0.71	0.63	1.19	1.09	3.95	3.31	0.68	0.57
1.1	0.77	0.62	0.77	0.70	3.60	2.93	0.77	0.61
1.2	0.82	0.63	0.15	0.04	2.98	2.36	0.81	0.62
1.3	0.82	0.60	0.70	0.70	2.38	1.83	0.82	0.59
1.4	0.75	0.53	0	0	1.95	1.43	0.83	0.58
1.5	0.61	0.40	0.30	0.30	1.71	1.19	0.87	0.59
1.6	0.46	0			1.58	1.04	0.91	0.60
1.7	0.32	0.70			1.48	0.93	0.92	0.60
1.8	0.21	0			1.32	0.81	0.88	0.56
1.9	0.04	0.30			1.11	0.67	0.80	0.51
2.0	0				0.87	0.52	0.69	0.44
2.1	0				0.65	0.24	0.57	0.36
2.2	0				0.47	0	0.47	0.15
2.3	0				0.33	0.70	0.37	0
2.4	0				0.24	0	0.00	0.70
2.5	0.70				0.02	0.30	0	0
2.6	0				0		0.70	0
2.7	0				0		0	0.30
2.8	0				0.70		0.30	
3.2	0.30				0.30			
TOTAL	14.68	14.05	10.01	9.40	38.00	30.13	15.00	11.48
> 1 V	5.03	3.16	1.15	1.04	18.09	12.02	9.94	6.60
> 2 V	1.00	0	0	0	2.71	1.24	2.41	1.51

Figure 7-1
Sequoyah Unit-1 SG 1
Predicted Bobbin Voltage Distribution for Cycle 8

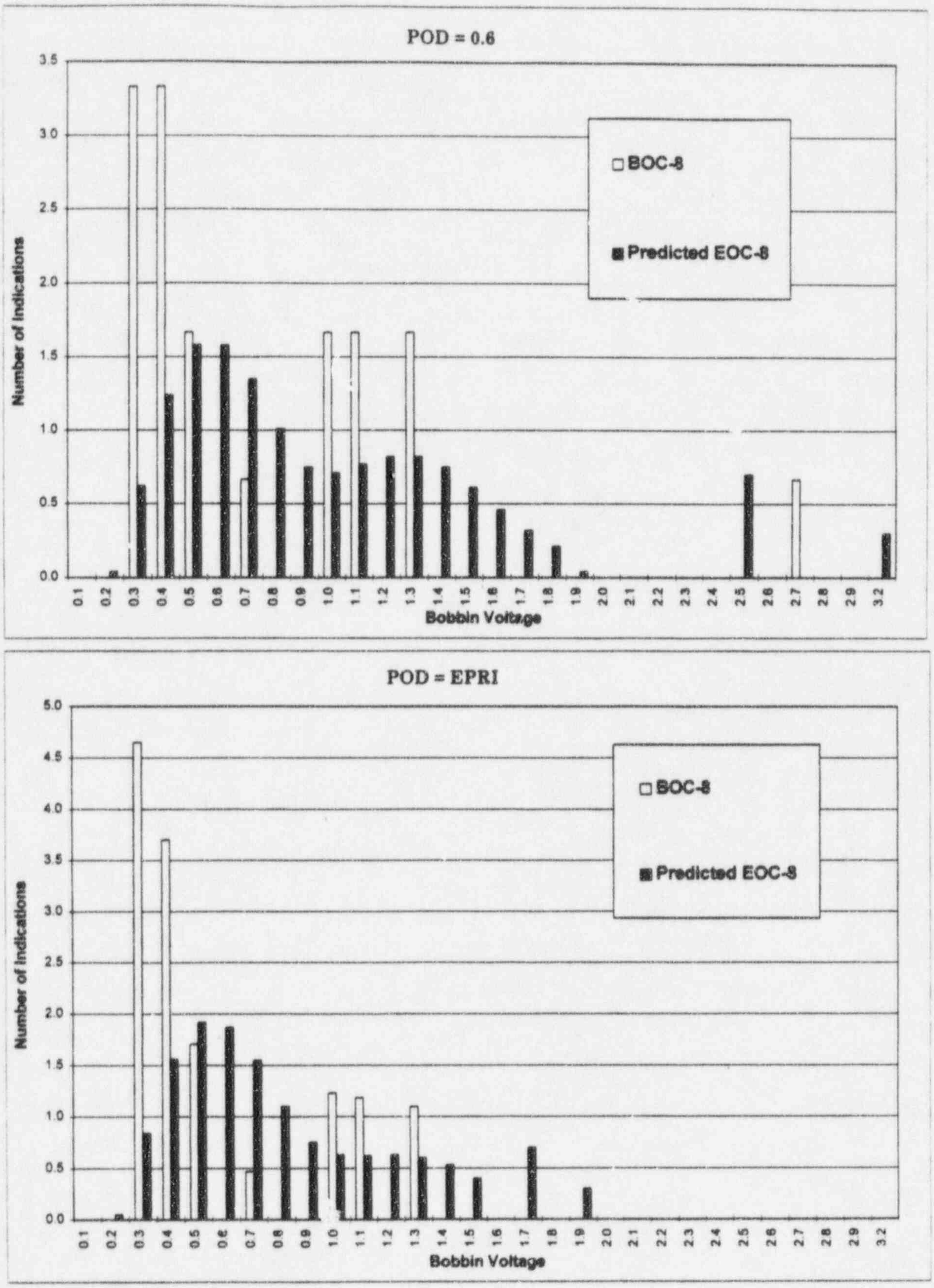


Figure 7 - 2
Sequoyah Unit-1 SG 2
Predicted Bobbin Voltage Distribution for Cycle 8

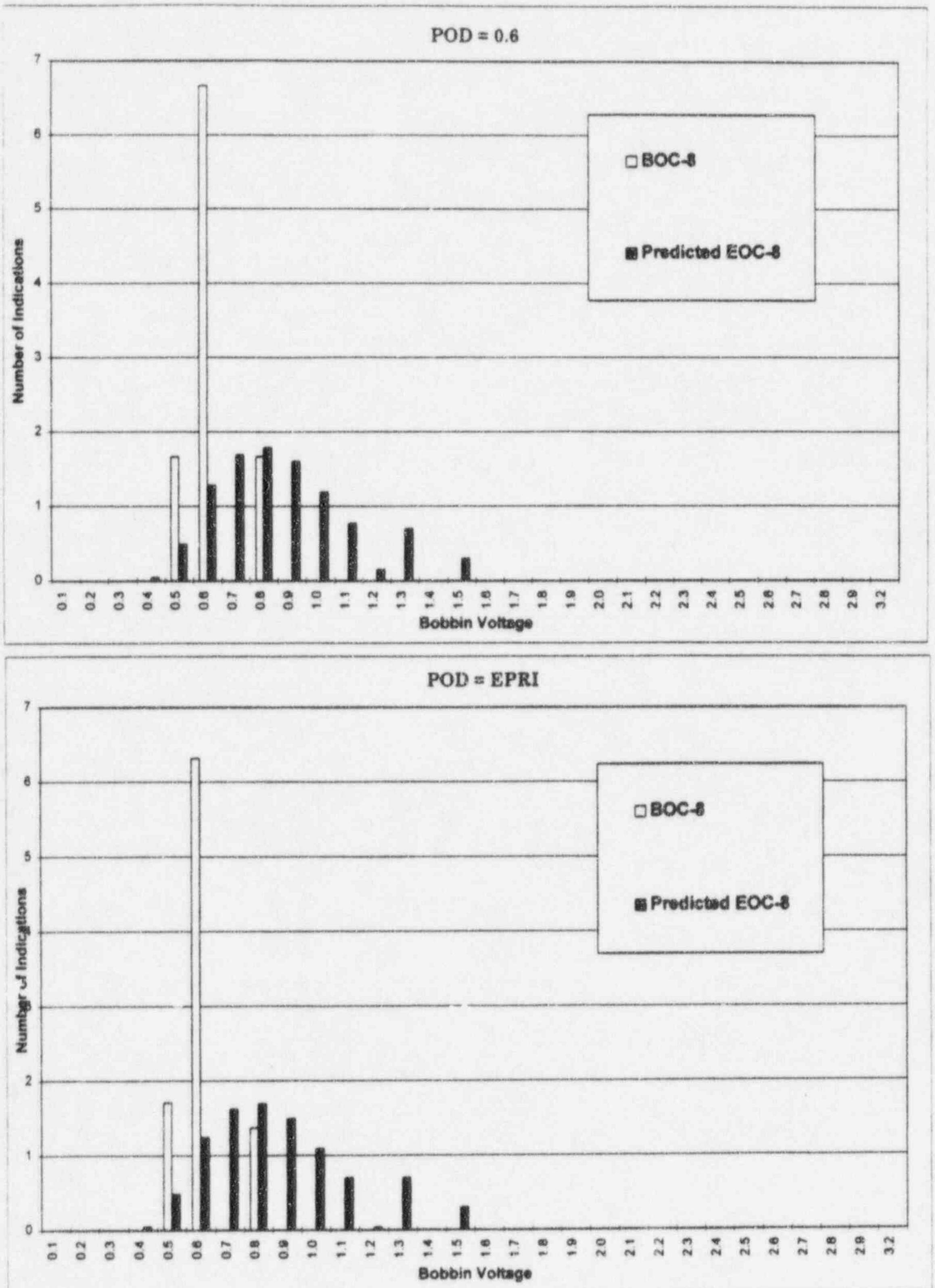
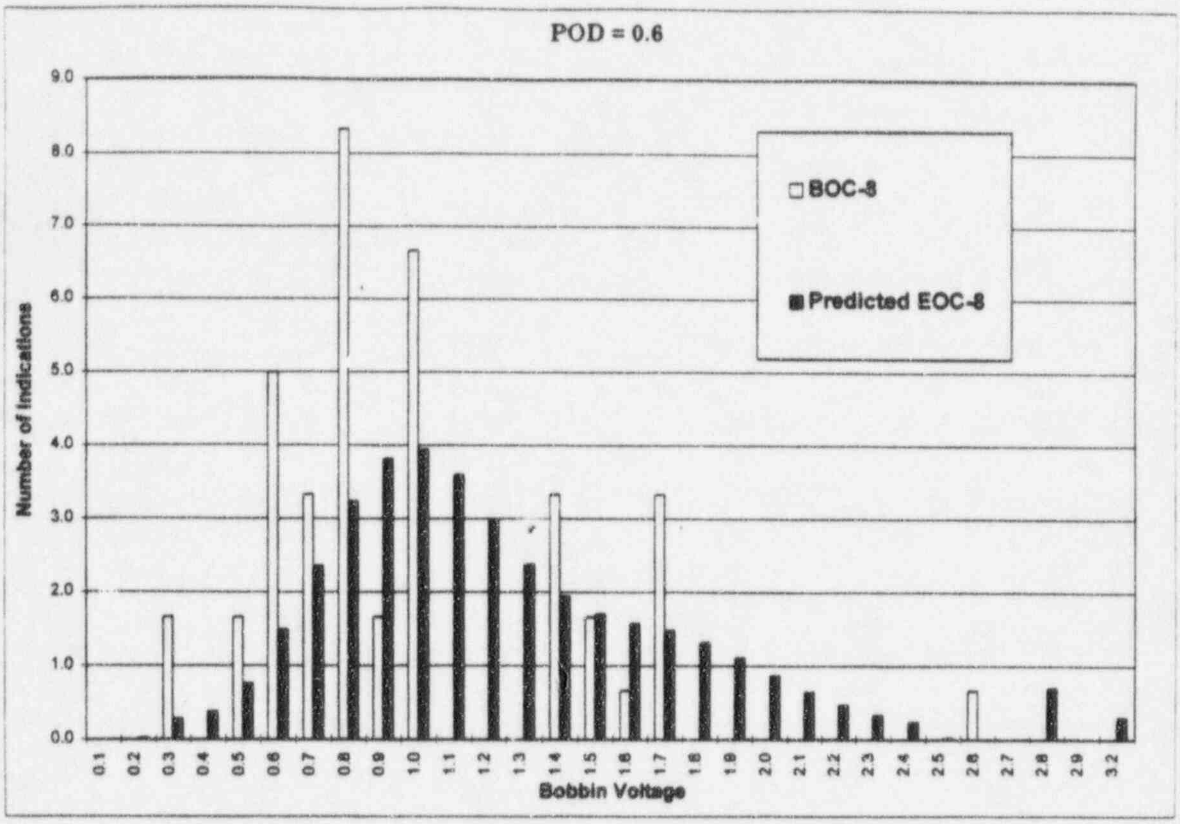


Figure 7 - 3
Sequoyah Unit-1 SC 3
Predicted Bobbin Voltage Distribution for Cycle 8


POD = 0.6

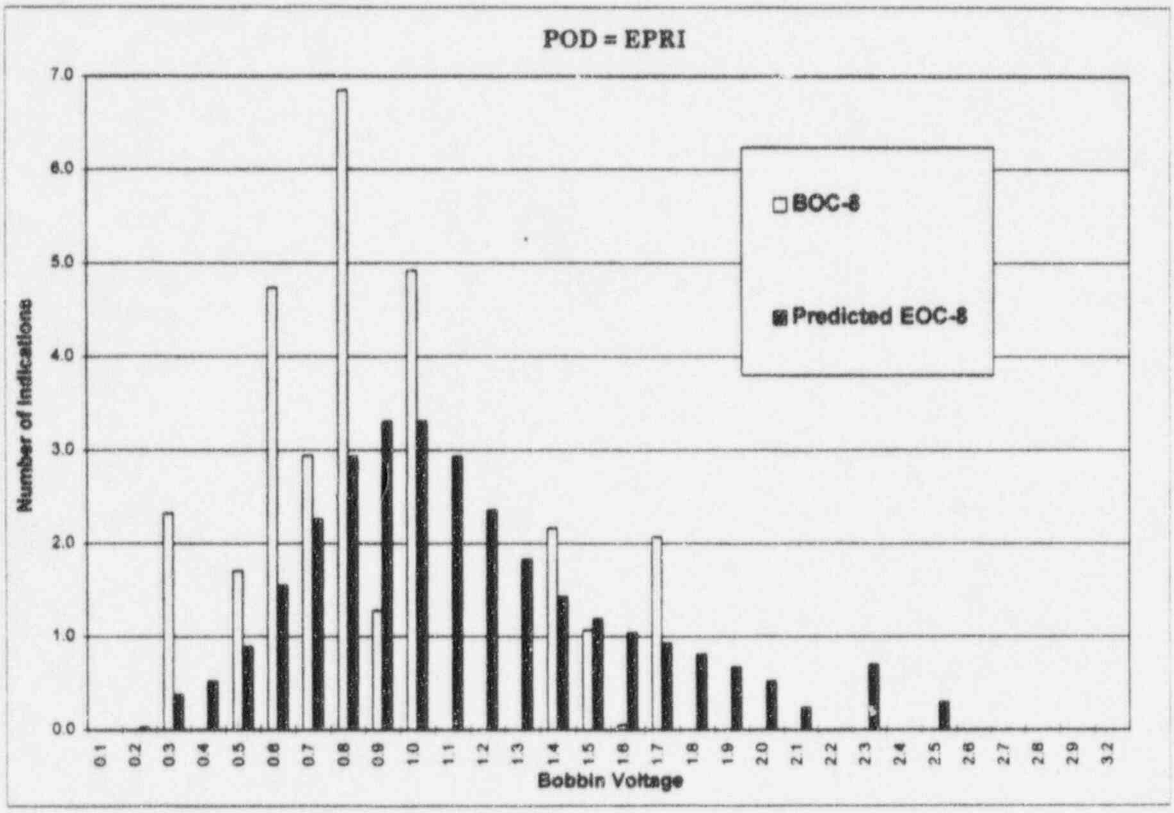
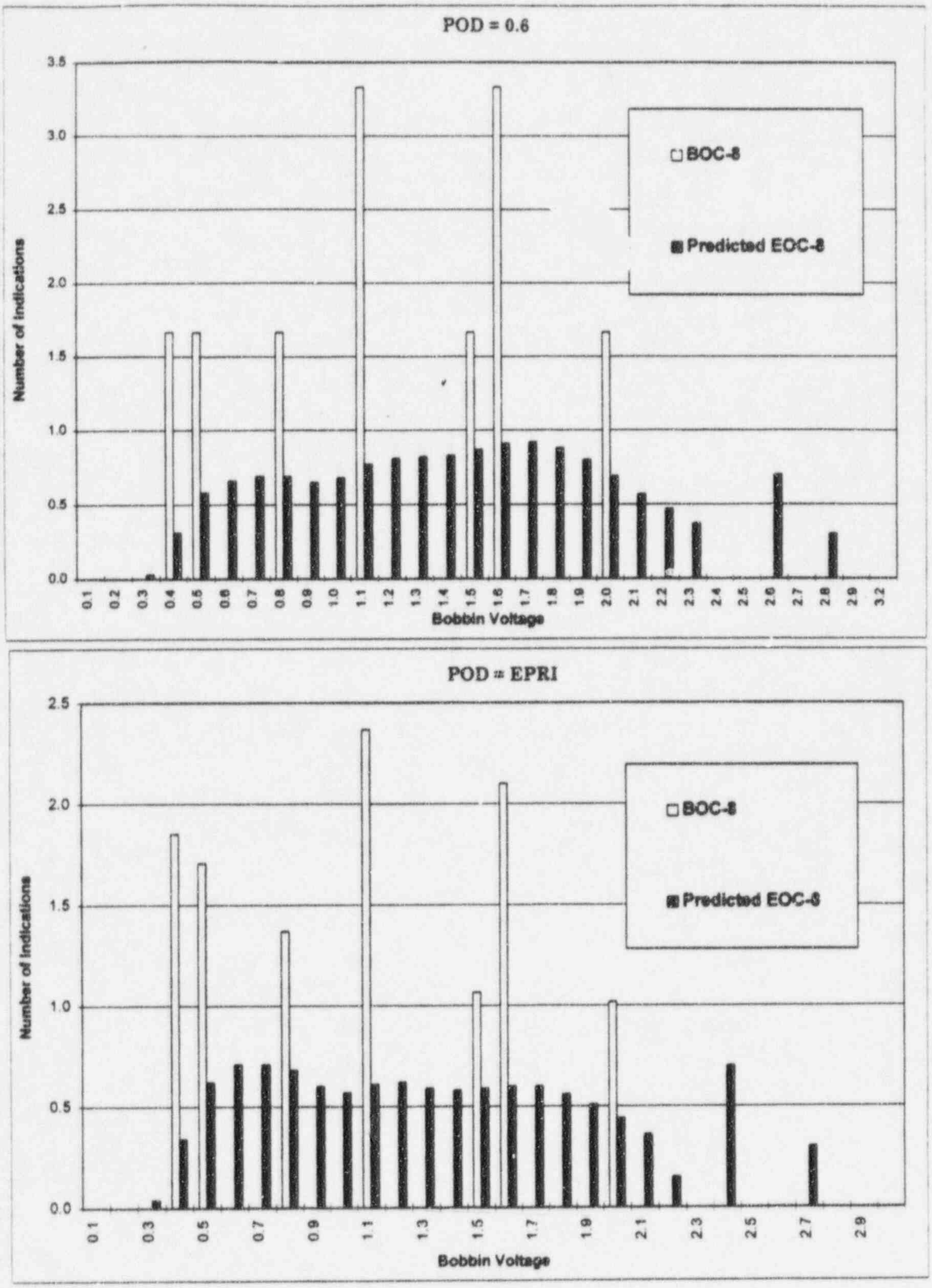

POD = EPRI

Figure 7 - 4
Sequoyah Unit-1 SG 4
Predicted Bobbin Voltage Distribution for Cycle 8



8.0 SLB LEAK RATE AND TUBE BURST PROBABILITY ANALYSES

8.1 Calculation of Leak Rate and Tube Burst Probability

Correlations have been developed for the evaluation of ODSCC indications at TSP locations in steam generators of nuclear power plants which relate bobbin voltage amplitudes to free span burst pressure, probability of leakage and associated leak rates. The Westinghouse methodology used in the calculation of these parameters, documented in References 9.2 and 9.3, is consistent with NRC criteria and guidelines of References 9.1.

8.2 Predicted Leak Rate and Tube Burst Probability

Using the methodology previously described, analyses were performed to calculate SLB tube leak rate and probability of burst values for the EOC-7 condition based on the measured voltage distributions as well as for the projected EOC-8 voltage distributions. The results of Monte Carlo calculations performed are summarized on Table 8-1. Calculations for the EOC-7 conditions were carried out only for SGs 1 and 3 because their results are expected to bound the other two SGs. Steam Generators 3 and 1 rank first and second, respectively, in total number of indications, and also SG 1 has the indication with the largest measured bobbin voltage. Analyses for EOC-8 conditions were performed for all four SGs.

Because of small indication population present in the Sequoyah-1 steam generators, SLB leak rates and tube burst probabilities calculated are much lower than those calculated for other plants applying APC. From Table 8-1 it is evident that SG 3 is the limiting steam generator for both EOC-7 as well as EOC-8 conditions. The limiting SLB leak rate and tube burst probability calculated from the measured EOC-7 voltage distribution are 0.058 gpm and 1.32×10^{-5}, respectively. The corresponding results projected for EOC-8 condition using the NRC required POD value of 0.6 are 0.173 gpm and 2.55×10^{-5}. The results for both EOC-7 and EOC-8 conditions are well below the Sequoyah-1 allowable SLB limit of 3.7 gpm and the NRC reporting guideline for tube burst probability of 1.0 E-02. In summary, the Sequoyah Unit-1 steam generators meet and exceed the APC criteria with a substantial margin.

Table 8 -1
Sequoyah Unit-1 1995 Outage
Summary of SLB Tube Leak Rate and Burst Probability

Steam Generator	POD	No. of Indications	Max. Volts[#]	Burst Probability		SLB Leak Rate gpm
				1 Tube	≥ 1 Tube	
EOC-7 Actual						
1	1	10	2.8	6.05 E-06	< 1 E-06	0.011
3	1	24	2.8	1.32 E-05	< 1 E-06	0.058
EOC-8 Predicted						
1	0.6	15	3.2	1.7 E-05	< 1 E-06	0.034
1	EPRI	14	1.9	5.29 E-06	< 1 E-06	0.006
2	0.6	10	1.5	< 1 E-06	< 1 E-06	< 0.001
2	EPRI	9	1.5	< 1 E-06	< 1 E-06	< 0.001
3	0.6	38	3.2	2.55 E-05	< 1 E-06	0.173
3	EPRI	30	2.5	1.22 E-05	< 1 E-06	0.083
4	0.6	15	2.8	1.90 E-05	< 1 E-06	0.077
4	EPRI	12	2.7	9.29 E-06	< 1 E-06	0.037

[#] Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.

9.0 REFERENCES

9.1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking", USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

9.2 WCAP-13990, "Sequoyah Units 1 and 2 - Steam Generator Plugging Criteria for Indications at the Tube Support Plate", Westinghouse Nuclear Services Division, May 1994.

9.3 WCAP-14277, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections", Westinghouse Nuclear Services Division, Jan.1995.

9.4 EPRI Report NP-7480-L, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Criteria, Volume 1: 7/8 Inch Diameter Tubing," Revision 1, December 1993.

9.5 EPRI Draft Report TR-100407, "PWR Steam Generator Tube Repair Limits - Technical Support Document for Outside Diameter Stress Corrosion Cracking at Tube Support Plates, Revision 1, August 1993.

ATTACHMENT 2

WESTINGHOUSE ELECTRIC CORPORATION

NUCLEAR SAFETY EVALUATION CHECKLIST SECL 95-154

SECL-95-154 Rev. 2
Page 1 of 12

Customer Reference No(s).
N/A
Westinghouse Reference No(s).
N/A

WESTINGHOUSE
SAFETY EVALUATION CHECK LIST

1) NUCLEAR PLANT(S): Sequoyah Nuclear Plant Unit 1

2) CHECK LIST APPLICABLE TO: Steam Generator Tube Integrity for Cycle 8 Operation

3) The written safety evaluation of the revised procedure, design change or modification required by 10CFR50.59 has been prepared to the extent required and is attached. If a safety evaluation is not required or is incomplete for any reason, explain on Page 2. Parts A and B of this Safety Evaluation Check List are to be completed only on the basis of the safety evaluation performed.

CHECK LIST - PART A

3.1) Yes__ No X A change to the plant as described in the FSAR?
3.2) Yes__ No X A change to procedures as described in the FSAR?
3.3) Yes__ No X A test or experiment not described in the FSAR?
3.4) Yes__ No X A change to the plant technical specifications (Appendix A to the Operating License)?

4) CHECK LIST - PART B (Justification for Part B answers must be included on page 2.)

4.1) Yes__ No X Will the probability of an accident previously evaluated in the FSAR be increased?
4.2) Yes__ No X Will the consequences of an accident previously evaluated in the FSAR be increased?
4.3) Yes__ No X May the possibility of an accident which is different than any already evaluated in the FSAR be created?
4.4) Yes__ No X Will the probability of a malfunction of equipment important to safety previously evaluated in the FSAR be increased?
4.5) Yes__ No X Will the consequences of a malfunction of equipment important to safety previously evaluated in the FSAR be increased?
4.6) Yes__ No X May the possibility of a malfunction of equipment important to safety different than any already evaluated in the FSAR be created?
4.7) Yes__ No X Will the margin of safety as defined in the bases to any technical specification be reduced?

If the answers to any of the above questions are unknown, indicate under 5) REMARKS and explain below.

If the answer to any of the above questions in Part (3.4) or Part B cannot be answered in the negative, the change review requires an application for license amendment in accordance with 10 CFR 50.59 (c) and submitted to the NRC pursuant to 10 CFR 50.90.

5) REMARKS:

The answers given in Section 3, Part A, and Section 4, Part B, of the Safety Evaluation Checklist, are based on the attached Safety Evaluation.

Reference document(s):

See Section 6.0 of this evaluation.

FOR FSAR UPDATE

Section: N/A Pages: _____ Tables: _____ Figures: _____

Reason for / Description of Change:

N/A

SIGNATURES

Prepared by: WK Cull W. K. Cullen Date: 2/1/96

Reviewed by: G. W. Whiteman Date: 2/1/96

Licensing: J. Fasnacht Date: 2/1/96

Sequoyah Nuclear Plant Unit 1
Steam Generator Tube Integrity for Cycle 8 Operation

1.0 INTRODUCTION

During the recent refueling and maintenance outage at the Sequoyah Nuclear Plant Unit 1 several types of off-nominal tube degradation phenomena were detected. These are: 1) axial cracking at dented tube support plate (TSP) intersections which extend beyond the plate, 2) circumferential degradation at dented TSP intersections, and 3) circumferential cracking at the tube expansion transition at the top of the tubesheet region. The latter has been previously identified at Sequoyah, and while not a new phenomena, the presence of such indications will be discussed along with the axial and circumferential indications at the dented TSP intersections.

During the application of chemically enhanced pressure pulse cleaning (PPCC) at Sequoyah Unit 1, the PPCC cleaning solution was observed to be leaking from the secondary to primary side as the solution was dripping into the channelhead bowl from tube location R2 C13, hot leg side in steam generator 2. Subsequent inspection indicated a circumferential crack located at the bottom side of the first tube support plate (TSP). This tube location is in a previously identified critical pulser zone region which based on calculations, could result in circumferential crack propagation (for circumferential cracks located at the top of the tubesheet region in the expansion transition). The Sequoyah Unit 1 plant has an extensive rotating pancake coil (RPC) inspection history for dented TSP intersections and circumferential cracking at these intersections has not previously been identified. It is believed that the circumferential crack in tube R2 C13, S/G 4 was propagated due to the dynamic effects of the PPCC process.

The purpose of this evaluation is to develop an overall tube bundle integrity evaluation for the three phenomena listed above. This evaluation demonstrates that the integrity of the tube bundle will be maintained following the PPCC, and that operation of the Sequoyah Unit 1 plant during Cycle 8 does not represent an unreviewed safety question as defined in 10 CFR 50.59.

2.0 REGULATORY BASIS

The NRC Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes", issued for comment, addresses tubes with throughwall and part throughwall degradation. Any crack morphology that is projected to result in a condition such that the Reg Guide burst requirements are not met at the end of the following cycle when a corrosion growth allowance for continued degradation and eddy current uncertainty are considered is unacceptable for continued operation. The RG uses safety factors on loads for tube burst that are consistent with the design criteria of Section III of the ASME Code. Its use establishes a reactor coolant system pressure boundary that should have an extremely low probability of abnormal leakage, rapidly propagating failure or gross rupture.

The steam generator tubes are part of the reactor coolant system (RCS) pressure boundary and a loss of tube integrity can result in leakage of primary coolant to the secondary side of the steam generator. The leakage of primary coolant has two major safety implications; the potential for the direct release of radioactive fission products to the environment and the loss of core cooling water.

The NRC regulations establish the fundamental requirements relative to steam generator tube integrity. General Design Criteria (GDC) of 10 CFR 50 Appendix A state that the reactor coolant system pressure boundary shall have an extremely low probability of abnormal leakage and shall be designed to permit periodic inspection and testing to assess structural and leaktight integrity. Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes" describes a method acceptable to the NRC staff for establishing the safe limiting conditions of degradation of steam generator tubing. Regulatory Guide 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes," defines defective tubes (i.e., tubes with wall thickness less than minimum wall thickness) as being unacceptable for continued service and recommends that these tubes be plugged.

3.0 EVALUATION

3.1 Establishment of Structural Limit for Axial and Circumferential Degradation

3.1.1 Structural Limit for Circumferential Degradation

Per RG 1.121, tube burst integrity is recommended for free span indications such that the burst capacity exceeds three times the normal operation primary to secondary pressure difference. Previously established top of tubesheet circumferential cracking structural prediction models can be used to define the throughwall (TW) circumferential crack for Sequoyah which meets the most limiting (3ΔP) RG 1.121 burst criteria and is established to be 247° TW for the single, 100% TW, uniform crack model. For the model which describes the crack as a uniformly deep crack extending 360° around the tube circumference, the crack depth which satisfies the same burst capacity is limited to 69% TW. The limiting single 100% TW crack length which provides a burst capability of 1.4 times the SLB ΔP is found to be 284°.

3.1.2 Structural Limit for Axial Indications

The structural limit for axial indications is dependent upon the total crack length and depth, as is the case for circumferential indications. For the limiting RG 1.121 burst capability of 3ΔP, the single axial TW crack length is determined to be 0.48", while the 1.4 SLB ΔP single TW crack length is found to be 0.571".

3.2 Discussion of Examination Results for Circumferential Indications at Dented TSP Intersections

A total of 24 circumferential indications were detected at dented TSP intersections. Of these, 22 are located at the first hot leg TSP and 15 are located in the PPC pulser nozzle outlet region at the first TSP. The remaining indications are located at the second and third TSP elevations. Only three of the indications were determined to be greater than 100° arc in length; R10 C2, S/G 1; R1 C69, S/G 3; and R2 C13, S/G 4. The indicated crack angles for these tubes are 110°, 127°, and 233°. (2)

The RPC trace for the first TSP region of R2 C13 S/G 4 is provided in Reference 1. The results of the evaluation of the RPC data for this tube are summarized below:

Total crack length:	233°
Average depth over crack angle	89% TW
Average depth over 360°	59% TW
Throughwall length	< 160°
Length > 90% TW depth	< 200°

As it is believed this indication started as a circumferential indication of small extent and was propagated as a result of the PPC loadings, a model of the tube was generated that included a crack element at the bottom surface of TSP 1. Pressure pulse loadings were then applied, and the dynamic response of the tube determined. The rate of crack propagation was then determined for various initial crack sizes and PPCC introduced bending stress levels. The initial 100% throughwall crack size needed to support fatigue propagation due to PPCC pulsing stresses varies from 30 to 50° and 50 to 75°, depending upon the bending stress condition assumptions and material fatigue propagation rates. This is consistent with the pressure pulse nozzle outlet tube inspection map which indicates that location R2 C13 is located in a zone of the inspection region which would result in crack propagation for initial crack sizes greater than the detection threshold but less than 100°. Similarly, R1 C69 is located in a region where initial crack sizes between 100 and 200° would propagate due to PPCC loadings. As such, neither of these indications should be considered in subsequent growth considerations.

Tube location R11 C61, S/G 1 was pulled. A circumferential indication was detected at the first TSP. Crack lengths and depths were determined to be 76° and 38% average TW using the RPC coil and 66° and 54% average TW using the Plus Point coil. Destructive examination showed circumferential extent of 65° with an average depth of 41% TW. Room temperature burst pressure was found to be ~10,000 psi, and the burst opening was axial in orientation, which is typical for circumferential cracks of limited angular extent.

3.3 Discussion of NDE Results for Top of Tubesheet Circumferential Crack Indications

A total of 85 top of tubesheet circumferential indications were detected in the WEXTEX expansion transition region. The breakdown on a per generator basis is as follows:

S/G 1	4 indications
S/G 2	43 indications
S/G 3	19 indications
S/G 4	19 indications

No circumferential cracks were detected in the PPCC pulser nozzle outlet region. The two largest circumferential indications were found in S/G 2, tube location R15 C23 (336°), and in S/G 4, tube location R14 C41 (281°). These two tubes are located in the central region of the tube bundle where WEXTEX region degradation is most likely based on sludge deposition with subsequent tube insulating effects causing elevated tube temperatures at the top of the tubesheet. The 1993 RPC data for these tubes was reevaluated, and based on this hindsight review, the apparent growth rates for these indications were determined to be 61° and 19°, respectively. Of the 85 total circumferential indications at the top of tubesheet, only 3 had crack angles greater than 200°, and only 10 had crack angles in excess of 150°. As the numbers of indications are uncharacteristic of recent inspection programs at Sequoyah, the large number of top of tubesheet indications could be partly attributed to an inspection transient event.

3.3.1 Discussion of R15 C23, S/G 2 Examination Results

This indication was the largest detected circumferential indication at the top of tubesheet elevation. An attempt was made to pull this tube, however, the tube separated at the crack elevation during removal. Examination of the fracture face was performed to establish the extent of the circumferential corrosion. A summary of the eddy current and destructive examination results are provided below:

	NDE Results	Destructive Exam Results
Total crack angle:	336°	6 cracks totalling 175° arc
Average depth over crack angle:	44% TW	53% TW
Average depth over 360°	41% TW	26% TW
Throughwall length:	< 10°, likely not TW	N/A: 85% TW max depth
Length > 90% deep:	< 10°	25° (length >80% deep)

Based on the tubesheet location of this tube, crack propagation due to PPCC was not expected.

3.4 Discussion of Axial Indications Extending Outside of the TSP Region

Of the 43 total axial indications in dented TSP intersections, 7 were found to partly extend outside of the TSP thickness. Of these 7, 6 had a total crack length of less than 0.4 inch and were judged to not require further evaluation merely on their total length. A free span, single 100% throughwall crack of approximately 0.48 inch length would provide for burst integrity at the 3 times normal operating pressure differential value.

The limiting axial indication, R11 C71, TSP 1, S/G 3, had a total crack length of 1.05", and average crack depth of 62% throughwall. The portion of the crack which extended beyond the plate was 0.53" long, with maximum degradation depth of 100% throughwall for ~0.1", and average depth of 71% throughwall over the exposed portion of the crack.

Generally, the axial indications extending outside of the plate had shallow average depths while the deeper sections of the macrocrack were short (<0.1") in length.

3.5 Tube Integrity Assessment

Based on the previous discussions, an assessment of the tube integrity characteristics projected to the end of the next operating cycle can be made.

3.5.1 Axial indications at Dented TSP Intersections

Using the RPC depth profile estimates, the burst pressures of all axial indications (regardless of extent outside of the TSP thickness) exceeded the RG 1.121 3ΔP recommendation. In the worst case, similar tube integrity conditions would be expected at the end of Cycle 8 since the Cycle 8 length in effective full power days (EFPD) is approximately equal to the Cycle 7 EFPD value (471 EFPD vs. 450 EFPD) and plant operating conditions remain unchanged. As the majority of the denting at Sequoyah occurred in the first operating cycle and is not progressing, stress levels due to denting are not expected to change significantly during the next cycle, and therefore there is no basis to postulate more rapid axial crack growth rates.

The limiting dented TSP intersection axial crack, found in tube location R11 C71 TSP 1, S/G 3, was determined to exhibit a burst pressure of ~6120 psi. This burst pressure was calculated considering only the length of the crack extending outside of the plate. If it is assumed that the indication acts like free span degradation (no credit taken for the plate), the calculated burst pressure for TSP 1 of R11 C71 is found to be ~5380 psi

A review of the previous cycle bobbin inspection history for the dented TSPs with significant axial indications has been performed. Of these, the largest axial growths have been determined to be 0.14 inch and 0.05 inch. As single throughwall cracks of approximately 0.48 inch in length, totally extending outside of the TSP thickness would exhibit a burst capability of approximately 3 times the normal operating pressure differential, application of the 0.14 inch maximum growth allowance to cracks existing at just below the detection threshold would not result in EOC cracks which could challenge tube structural integrity acceptance criteria as prescribed by the RG.

3.5.2 Circumferential Indications at Dented TSP Intersections

The number of circumferential cracks detected at dented TSPs, 24, represents approximately 0.36% of the total number of dented TSPs intersections. (2)

As a bounding growth rate allowance, a value of 110° for circumferential indications at dented TSPs can be applied. This value is taken from tube R10 C2, S/G 1. The two other larger TSP circumferential indications are subject to crack propagation due to fatigue, and therefore are not appropriate to use for a growth allowance to determine RG 1.121 compliance. Circumferential crack growth is usually dominant in the arc length dimension as opposed to throughwall depth. That is, the 100% throughwall distance is usually short compared to the overall crack length. A more appropriate growth allowance would be to use the average of the total arc lengths of the 22 TSP circumferential indications not subject to PP/CC propagation, or, approximately 72°. When the detection threshold is added, the EOC crack is bounded by (2) the single throughwall circumferential crack length of 247°. The growth allowance added to the detection threshold in this case is assumed to result in a single uniform throughwall crack equal to the total crack length represented by the sum of the detection threshold and the growth allowance. Previously published industry data suggests that the detection threshold of the 3-coil RPC is approximately 40° arc for degradation of 50% throughwall and 23° arc for 100% throughwall indications. The Plus Point probe was used for the dented TSP inspections at Sequoyah Unit 1. Detection thresholds for the Plus Point probe are expected to be equal to or superior to the 3-coil RPC, which was used for the 1993 dented TSP inspections. Due to the probe type variance between 1993 and 1995, it was judged that a one-to-one comparison of growth rates was not appropriate. Adding the growth allowance to the detection threshold, and assuming the resultant crack is throughwall over the resultant arc length is quite conservative since not only must the crack grow in arc length, but must also grow in depth by an uncharacteristic amount. Regardless of the crack growth from the 1993 inspection to the 1995 inspection, EOC circumferential crack angles at dented tube support plate intersections are less than the single throughwall crack structural limit of 247°, and as a worst case, EOC crack conditions at the end of the next operating cycle would be expected to be bounded by the latest inspection results.

Additionally, as the TSP denting at Sequoyah Unit 1 occurred during the first cycle of operation and has not significantly progressed since, the stress patterns in the dented intersections are not expected to change. Localized chemistry conditions which could act as a corrosion accelerator have been effectively removed by the chemical cleaning. Therefore, there is no basis to suggest corrosion rates greater than previously experienced.

3.5.3 Circumferential Indications at the Top of Tubesheet Region

A total of 85 circumferential indications were detected at the TTS region. Of these 85, only three were over 200° in arc length (336, 281, and 205°), while only 10 had arc lengths greater than 150°. Based on the eddy current depth profiles and pulled tube destructive exam results, these tubes were determined to maintain burst integrity in excess of the RG 1.121 recommendations at the end of Cycle 7. Using the destructive exam data for R15 C23, S/G 2, the estimated burst pressure was determined to be 7800 psi, while the burst pressure using NDE was determined to be >6000 psi. The burst pressure for the 281° indication was also determined to be >6000 psi.

Based on a hindsight review, the maximum associated circumferential angle growth is estimated to be 61°. When the 61° growth rate is included with the assumed detection thresholds for the 3-coil RPC, the EOC crack angle is projected to be well within the EOC structural limit of 247° for single throughwall circumferential indications. As with the TSP evaluation, the growth rate allowance is assumed to represent 100% throughwall crack growth, and is quite uncharacteristic for WEXTEX indications. The pulled WEXTEX tube specimens with circumferential degradation have indicated a segmented morphology, with numerous ductile ligaments separating multiple crack initiation sites. The structural limit for segmented crack morphologies has been previously established to be approximately 297° for a $3\Delta P$ value more limiting than current conditions at Sequoyah. As the Sequoyah morphology was found to segmented, the practical structural limit based on RG 1.121 limitations will exceed 247° and approach 297°.

3.6 Remedial Measures and Additional Safety Margins

3.6.1 Reduced Primary to Secondary Leakage Limit

Normal operation primary to secondary leakage was administratively reduced to 128 gpd when circumferential degradation was first detected at Sequoyah Unit 1. Existing data suggests that 100% throughwall circumferential cracks of about 70° would be expected to leak at a rate of approximately 128 gpd. Therefore, the plant operators will be alerted to this condition by the existing primary to secondary leakage detection methods. As cracks of up to 247° provide for structural integrity at the most limiting RG 1.121 pressure loading, the plant can be safely shutdown in a controlled manner, prior to the crack growing (by corrosion) to such an extent that structural integrity would be challenged.

3.6.2 Primary to Secondary Leakage During Cycle 7

TVA has reported to Westinghouse that the measured primary to secondary leakage during Cycle 7 was typically less than 1 gpd. This suggests that the detected circumferential degradation at the dented TSPs and the axial cracking which extends outside of the dented TSP regions was either not throughwall or not throughwall for an extent which could support leakage at the current normal operating primary to secondary pressure value. Throughwall depth estimations were not made for the dented TSP intersections. One other possible explanation for the low level of leakage experienced is sludge accumulation could have affected leakage from postulated throughwall cracks at the edges of dented TSPs. Additionally, only 7 of the identified 24 circumferential cracks at dented TSPs were located outside of the TSP. The corrosion product buildup which caused the denting could restrict leakage from postulated throughwall circumferential cracking at dented TSPs. The application of PPCC could have removed these deposits such that future developing cracks would not become restricted.

4.0 ASSESSMENT OF UNREVIEWED SAFETY QUESTION

Based on the Cycle 7 inspection results, operation of the Sequoyah Nuclear Plant Unit 1 during Cycle 8 does not involve an unreviewed safety question, based on the following justification.

1) May the proposed activity increase the probability of occurrence of an accident evaluated in the FSAR?

   No. Based on the extensive inspection plan performed during the recent outage at Sequoyah Unit 1 and the apparent growth rates determined by eddy current examination, no tubes would be expected to contain degradation in excess of the structural limits established in this report. Apparent growth rates of OD intiated degradation would be expected to be further suppressed by the effects of chemically enhanced pressure pulse cleaning, which has removed large sludge deposits from the secondary side of the steam generator as well as the tubes, in addition to the removal of deposited copper from the tubes. Copper can act as an oxidizer, thereby increasing crack growth rates. Therefore, as no tubes are expected to contain degradation in excess of the structural limits which provide for compliance with RG 1.121, the probability of occurrence of an accident evaluated in the FSAR, in particular, a steam generator tube rupture (SGTR) event, is not increased.

2) May the proposed activity increase the consequences of an accident evaluated previously in the FSAR?

   No. The response of the steam generator to postulated accident conditions is not adversely affected. Any hypothetical failure of a tube is bounded by the results of existing steam generator tube rupture analyses. The structural and leakage integrity of the tube bundle is enhanced subsequent to steam generator non-destructive examination and tube repair. Therefore, as tube structural integrity is expected to be maintained throughout the next cycle, continued operation will not increase the consequences of an accident previously evaluated in the FSAR.

3) May the proposed activity create the possibility of an accident of a different type than any evaluated previously in the FSAR?

   No. No new tube degradation phenomena is anticipated upon return to power. The postulated worst case EOC crack sizes for both axial and circumferential cracks provide substantial margin to the most limiting $3\Delta P$ burst recommendation of RG 1.121. As tube structural and leakage integrity are expected to be maintained during Cycle 8, there is no mechanism which could affect the steam generator tubes in a manner different that previously considered. Also, as tube structural and leakage integrity are expected to be maintained during the upcoming cycle, the potential for an accident outside of the design basis, such as a multiple tube rupture, is not created. Furthermore, the 128 gpd administrative steam generator tube normal operation leakage allowance implemented at Sequoyah Unit 1 will help to provide for early detection of throughwall cracking not predicted by the current available growth information which could possibly affect steam generator tube integrity during accident conditions.

4) May the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety evaluated previously in the FSAR?

No. There is no mechanism for any other component or system connecting with the steam generator to be affected during operation. Structural and leakage integrity are expected to be maintained during Cycle 8. The steam generators will perform in a manner consistent with the assumptions of the licensing basis.

5) May the proposed activity increase the consequences of a malfunction of equipment important to safety evaluated previously in the FSAR?

No. There is no mechanism for the steam generator tubes to affect the consequences associated with a malfunction of equipment important to safety as currently evaluated in the FSAR. The response of the steam generator to postulated accident condition loadings is not adversely affected. Any hypothetical failure of a tube is bounded by the results of existing steam generator tube rupture analyses. The integrity of the tube bundle is maintained during all plant conditions upon return to power.

6) May the proposed activity create the possibility of a malfunction of equipment important to safety of a different type than previously evaluated in the FSAR?

No. As structural integrity consistent with RG 1.121 will be provided during the operation of the Sequoyan Nuclear Plant Unit 1 during Cycle 8, integrity consistent with the design requirements of Section III of the ASME Code will be provided since the RG uses safety factors consistent with the Code. There is no mechanism to postulate operation or a malfunction of equipment different than currently evaluated in the FSAR.

7) Does the proposed activity reduce the margin of safety as defined in the basis for any technical specification?

No. The analysis to support the continued operation of the Sequoyah Unit 1 plant demonstrates that the ASME Code and Regulatory Guide 1.121 criteria continue to be met for the postulated loads and stress levels. The margin of safety with respect to primary pressure boundary is provided, in part, by safety factors included in these criteria, and is not reduced.

5.0 CONCLUSION

Based on the preceding evaluation, it has been concluded that the integrity of the Sequoyah Nuclear Plant Unit 1 steam generators is maintained during Cycle 8. The presence of non-detectable circumferentially oriented degradation at the TSP intersection or at the top of tubesheet region will not result in an end of cycle condition such that the burst recommendations of RG 1.121 are not maintained. Continued operation of the Sequoyah Nuclear Plant Unit 1 with postulated non-detectable circumferential cracking does not represent an unreviewed safety question according to the guidelines of 10 CFR 50.59 and does not involve a change to the plant Technical Specifications.

6.0 REFERENCES

1) Letter NSD-JLH-5372, "PPCC Induced Crack Propagation Analysis of R2 C13 at Sequoyah", October 9, 1995 **

2) WCAP-13034, "North Anna Unit 1 Steam Generator Operating Cycle Evaluation", August 1991 (Proprietary) **

3) NSD-TAP-3116, "Sequoyah-1 Tube Integrity Assessment", January 15, 1996

4) Telecon between F. Di Agostino (W), W. Cullen (W), and D. Hughes (TVA), 1/25/96

5) Telecon between W. Cullen (W), and D. Hughes (TVA), 1/31/96

**: Internal Westinghouse Reference