TVA NUCLEAR

Sequoyah Nuclear Plant

Unit 2 Cycle 7 Refueling Outage

April - June 1996

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

RESULTS OF ALTENATE PLUGGING CRITERIA IMPLEMENTATION
(AS REQUIRED BY COMMITMENT FROM TECHNICAL
SPECIFICATION CHANGE 95-23)

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INTRODUCTION

During the scheduled Sequoyah Nuclear Plant (SQN) Unit 2 Cycle 7 (U2C7) refueling outage extensive inservice inspections were conducted in all four steam generators (SGs). The results of the inspections were classified as C-2 for all four SGs. Alternate plugging criteria was implemented during this inspection due to the detection of outside diameter stress corrosion cracking at the tube support plate intersections.

A total of two tubes were pulled, one from each SG 2 and SG 3 for the implementation of the voltage based alternate plugging criteria.

This report fulfills the reporting requirements of SQN Technical Specification section 4.4.5.5.b for report results of SG inservice inspection. Table 1 indicates the number and extent of tubes examined. Table 2 lists the location and percent of wall penetration or degradation call for each indication. This table also identifies the tubes plugged during the refueling outage. This report also fulfills the report requirements of SQN Technical Specification change 95-23 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 SGs 1 and 2, where approximately 17.5% of the cold leg in rows 1 through 10 from the 7th cold leg support to the cold leg tube end were not examined). The bobbin coil exams were expanded to full length of all tubes due to the detection of outside diameter stress corrosion cracking (ODSCC) detected at cold leg tube support plates. The initial sample in all four SGs for rotating pancake coil (RPC) inspection at dented tube support plate (TSP) intersections (>5 volts by bobbin coil) was 100% of the affected hot leg TSPs. Due to the detection of ODSCC in the cold leg, RPC inspection was expanded to cold leg dented TSPs (>5 volts by bobbin coil). The initial sample for row 1 and 2 U-bend examination with RPC was 20 percent in each SG. Due to the detection of PWSCC in row 1 U-bends 100% of row 1 tubes were examined in all SGs and 100% of the row 2 U-bends were inspected in SGs 2, 3 and 4. The initial sample for the rotating pancake coil examination of the WEXTEX transition region was approximately 48 percent of the hotleg tubes in each SG. Due to the detection of expansion transition primary water stress corrosion cracking (PWSCC), the RPC examination scope was expanded to 100% in SG 2, and 55% in SGs 3 and 4.

Table 1 summarizes the SQN U2C7 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 U2C7 Outage, provides a summary of the tube damage detected and a characterization of the damage morphology.

The SG tube degradation detected were 1) Top-of-tubesheet (TTS) PWSCC, 2) Outside Diameter Stress Corrosion Cracking (ODSCC) at non dented TSP intersections, 3) Low Row U-bend PWSCC, 5) Anti-Vibration Bar (AVB) Wear, and 6) Cold Leg Wastage. TTS RPC exams detected axial PWSCC located in the central region of the tube bundle where WEXTEX degradation is most likely due to high tube temperatures at the top of the tubesheet and exasperated by sludge deposits creating an insulating affect. No circumferential PWSCC was detected during these inspections.

ODSCC was detected at non-dented intersections during the Unit 2 Cycle 7 outage and Alternate Plugging Criteria was implemented. A total of 367 indications were identified in a total of 344 tubes and 342 tubes were left in service. ODSCC was detected in the cold leg of the SQN SGs, which instigated a tube pull in SG 2 from the cold leg to verify the eddy current signals are stress corrosion cracking. Due to the detection of indications of TSP ODSCC in the cold leg RPC inspections were performed on cold leg wastage indications to

verify the indications were not crack like. 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.

Low row U-bend PWSCC was detected with RPC examinations during the Unit 2 Cycle 7 outage. Seventeen tubes were removed from service. Historical data review of these indications was performed. It was determined that non-magnetically bias probes were used during the Unit 2 Cycle 6 inspection. All the row 1 indications detected during the Unit 2 Cycle 7 inspection were affected by permeability changes in the tubing which coincided with the flaw location in the previous inspection. The one row 2 indication detected during the Unit 2 Cycle 7 outage was not characterized as a crack-like indication, but was conservatively plugged.

There were a number of freespan indications identified by bobbin coil (Distorted Bobbin Coil Signals) in all four SGs that indicated a percent wall loss. All of these indications were examined by RPC and no crack-like indications were detected.

Minor AVB wear and cold leg wastage was detected with the bobbin coil examinations. Four tubes were plugged for AVB wear and three tubes were plugged for coldleg wastage. These results are identified in Table 1.

TABLE 1

SUMMARY OF SEQUOYAH UNIT 2 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	3363	3324	3350	3377	**13414**
Partial-length bobbin coil	0	0	0	0	**0**
Support plate MRPC	85	51	70	25	**231**
Freespan MRPC	25	16	19	128	**188**
Top of tubesheet MRPC	1654	3324	1867	1879	**8724**
U-Bend MRPC	98	166	174	188	**626**
TOTAL EXAMS COMPLETED	5225	6881	5480	5597	**23183**

INDICATIONS (TUBES)	S/G 1	S/G 2	S/G 3	S/G 4	Totals
Defects (>=40% wall loss)					
HTS PWSCC	0	9	4	2	**15**
COLD LEG WASTAGE	1	1	1	0	**3**
U-BEND PWSCC	0	6	7	4	**17**
AVB WEAR	2	2	0	0	**4**
Degradation (>=20% and <40% wall loss and APC indications)					
DIST BC SIGNAL	4	7	13	7	**31**
COLD LEG WASTAGE	2	9	4	3	**18**
FLOW LANE BLOCKING WEAR	0	0	0	1	**1**
AVB WEAR	8	16	7	2	**33**
PI (APC) OD CORROSION (Note 1)	43	52	88	161	**344**
Imperfections (<20% wall loss)					
COLD LEG WASTAGE	0	5	4	4	**13**
AVB WEAR	2	6	2	6	**16**
MANUFACTURING FLAWS	0	0	0	0	**0**

PLUGGING STATUS	S/G 1	S/G 2	S/G 3	S/G 4	Totals
Previously Plugged (as of U2C6)	25	64	38	11	**138**
Plugged Cycle 7					
HTS PWSCC	0	9	4	2	**15**
C/L WASTAGE	1	1	1	0	**3**
U-BEND PWSCC	0	6	7	4	**17**
OD TSP CORROSION (pulled tubes)	0	1	1	0	**2**
AVB WEAR	2	2	0	0	**4**
TOTAL TUBES PLUGGED	**28**	**83**	**51**	**17**	**179**

Note (1) SQN Unit 2 Technical Specification Change 95-23 implemented an Alternate Plugging Criteria which allows TSP ODSCC indications to remain in service when less than 2 volts amplitude (bobbin coil).

TABLE 2

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
1	2	70	PI	H02+.14	ODSCC TSP	(1)
1	2	75	PI	H02+.09	ODSCC TSP	(1)
1	3	34	PI	H01+.06	ODSCC TSP	(1)
1	5	26	PI	H02+.11	ODSCC TSP	(1)
1	5	46	PI	H01+.00	ODSCC TSP	(1)
1	8	31	<40	HTS+1.25	DIST. BC SIG.	(1)
1	8	32	<40	HTS+1.22	DIST. BC SIG.	(1)
1	9	32	<40	HTS+1.56	DIST. BC SIG.	(1)
1	9	39	PI	H01+.08	ODSCC TSP	(1)
1	10	18	PI	C01-.08	ODSCC TSP	(1)
1	11	61	PI	H02+.17	ODSCC TSP	(1)
1	13	62	PI	H05+.05	ODSCC TSP	(1)
1	15	28	PI	H01+.05	ODSCC TSP	(1)
1	15	38	<40	HTS+1.02	DIST. BC SIG.	(1)
1	17	50	PI	H05+.13	ODSCC TSP	(1)
1	17	82	PI	H05+.08	ODSCC TSP	(1)
1	19	38	29	AV2+.14	AVB WEAR	(1)
1	19	38	17	AV3+.00	AVB WEAR	(1)
1	20	58	PI	H01+.17	ODSCC TSP	(1)
1	25	28	PI	C07-.05	ODSCC TSP	(1)
1	26	15	PI	H02+.08	ODSCC TSP	(1)
1	26	15	PI	H02+.14	ODSCC TSP	(1)
1	27	31	17	AV2+.03	AVB WEAR	(1)
1	27	31	17	AV3-.03	AVB WEAR	(1)
1	27	48	PI	H02+.11	ODSCC TSP	(1)
1	27	64	PI	H04+.06	ODSCC TSP	(1)
1	28	28	PI	H04+.11	ODSCC TSP	(1)
1	28	45	PI	H02+.05	ODSCC TSP	(1)
1	29	13	28	AV2+.00	AVB WEAR	(1)
1	29	52	PI	H02+.05	ODSCC TSP	(1)
1	29	63	17	AV1+.00	AVB WEAR	PLUG
1	29	63	25	AV2+.00	AVB WEAR	PLUG
1	29	63	41	AV3+.00	AVB WEAR	PLUG
1	30	24	PI	C04-.14	ODSCC TSP	(1)
1	30	25	PI	C06-.03	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
1	30	80	PI	H06+.11	ODSCC TSP	(1)
1	30	83	PI	H05+.00	ODSCC TSP	(1)
1	30	83	PI	H06+.20	ODSCC TSP	(1)
1	31	82	PI	H05+.17	ODSCC TSP	(1)
1	32	64	20	AV2+.19	AVB WEAR	(1)
1	32	64	24	AV3+.03	AVB WEAR	(1)
1	32	64	18	AV4+.00	AVB WEAR	(1)
1	32	68	PI	H01+.08	ODSCC TSP	(1)
1	32	79	PI	H05+.14	ODSCC TSP	(1)
1	32	79	PI	H06+.14	ODSCC TSP	(1)
1	33	51	30	AV2+.00	AVB WEAR	(1)
1	33	51	21	AV3+.00	AVB WEAR	(1)
1	33	57	38	AV2+.00	AVB WEAR	PLUG
1	33	57	43	AV3+.00	AVB WEAR	PLUG
1	33	59	22	AV1+.77	AVB WEAR	(1)
1	33	59	28	AV2+.58	AVB WEAR	(1)
1	33	59	24	AV2-.55	AVB WEAR	(1)
1	33	59	32	AV3-.06	AVB WEAR	(1)
1	33	59	22	AV4+.97	AVB WEAR	(1)
1	34	19	31	C01+.19	C/L WASTAGE	(1)
1	34	23	PI	H01+.11	ODSCC TSP	(1)
1	34	32	PI	H05+.19	ODSCC TSP	(1)
1	34	53	38	AV2+.00	AVB WEAR	(1)
1	34	53	34	AV3+.00	AVB WEAR	(1)
1	34	79	PI	H05+.19	ODSCC TSP	(1)
1	35	30	10	AV2-.11	AVB WEAR	(1)
1	35	30	PI	H01+.08	ODSCC TSP	(1)
1	36	62	PI	H02+.11	ODSCC TSP	(1)
1	36	66	24	AV3+.00	AVB WEAR	(1)
1	37	62	20	AV2-.06	AVB WEAR	(1)
1	37	62	30	AV3-.06	AVB WEAR	(1)
1	38	65	PI	H04+.08	ODSCC TSP	(1)
1	40	26	PI	H05+.14	ODSCC TSP	(1)
1	40	69	PI	H01+.05	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
1	42	34	PI	H01+.19	ODSCC TSP	(1)
1	44	34	21	C01+.00	C/L WASTAGE	(1)
1	44	36	PI	H01+.16	ODSCC TSP	(1)
1	44	60	PI	H05+.11	ODSCC TSP	(1)
1	46	44	PI	C02-.03	ODSCC TSP	(1)
1	46	49	66	C02-.05	C/L WASTAGE	PLUG

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

Cold Leg Bobbin Coil Expansion

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
1	3	77	PI	C02+.00	ODSCC TSP	(1)
1	6	9	PI	C01+.03	ODSCC TSP	(1)
1	7	9	PI	C01-.05	ODSCC TSP	(1)
1	9	8	PI	C01-.05	ODSCC TSP	(1)

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

(1) Retest Future Outage
(2) None Required

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
2	1	23	SAI	H07+2.71	PWSCC U-BEND	PLUG
2	1	33	SAI	H07+2.63	PWSCC U-BEND	PLUG
2	1	34	MAI	H07+2.60	PWSCC U-BEND	PLUG
2	1	40	MAI	H07+2.67	PWSCC U-BEND	PLUG
2	1	48	MAI	H07+7.23	PWSCC U-BEND	PLUG
2	1	48	MAI	H07+7.28	PWSCC U-BEND	PLUG
2	2	21	SAI	H07+7.71	PWSCC U-BEND	PLUG
2	2	83	PI	H01+.03	ODSCC TSP	(1)
2	2	85	PI	H01+.06	ODSCC TSP	(1)
2	3	11	90	HTS-.64	PWSCC HTS	PLUG
2	3	11	SAI	HTS-1.09	PWSCC HTS	PLUG
2	3	42	PI	H02-.06	ODSCC TSP	(1)
2	3	72	PI	H01+.08	ODSCC TSP	(1)
2	4	2	PI	C07+.00	ODSCC TSP	(1)
2	4	26	PI	H02-.03	ODSCC TSP	(1)
2	4	69	SAI	HTS-1.94	PWSCC HTS	PLUG
2	4	69	SAI	HTS-2.39	PWSCC HTS	PLUG
2	5	54	SAI	HTS-.82	PWSCC HTS	PLUG
2	6	3	PI	H01+.00	ODSCC TSP	(1)
2	6	43	PI	H02+.08	ODSCC TSP	(1)
2	6	78	SAI	HTS-1.42	PWSCC HTS	PLUG
2	6	93	28	C01+.14	C/L WASTAGE	(1)
2	7	4	PI	H01+.03	ODSCC TSP	(1)
2	7	4	PI	H02+.08	ODSCC TSP	(1)
2	7	20	PI	H04+.14	ODSCC TSP	(1)
2	7	50	SAI	HTS-.58	PWSCC HTS	PLUG
2	8	61	PI	H02-.25	ODSCC TSP	(1)
2	9	57	PI	H02-.06	ODSCC TSP	(1)
2	9	72	PI	H02-.33	ODSCC TSP	(1)
2	10	8	PI	H05+.06	ODSCC TSP	(1)
2	10	39	PI	H01-.08	ODSCC TSP	(1)
2	10	56	SAI	HTS-1.15	PWSCC HTS	PLUG

TABLE 2

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	11	39	SAI	HTS-.52	PWSCC HTS	PLUG
2	11	55	<40	HTS+1.82	DIST. BC SIG.	(1)
2	12	35	PI	H01+.00	ODSCC TSP	(1)
2	12	63	<40	HTS+2.18	DIST. BC SIG.	(1)
2	12	92	34	C01-.05	C/L WASTAGE	(1)
2	13	15	PI	H04+.00	ODSCC TSP	(1)
2	13	15	PI	H05-.05	ODSCC TSP	(1)
2	14	42	<40	HTS+1.98	DIST. BC SIG.	(1)
2	14	48	PI	H01+.05	ODSCC TSP	(1)
2	14	54	<40	HTS+1.08	DIST. BC SIG.	(1)
2	15	33	PI	H01+.08	ODSCC TSP	(1)
2	15	54	PI	H02-.03	ODSCC TSP	(1)
2	15	54	<40	HTS+2.43	DIST. BC SIG.	(1)
2	15	89	PI	H01+.05	ODSCC TSP	(1)
2	17	28	15	AV1+.00	AVB WEAR	(1)
2	17	28	29	AV3-.21	AVB WEAR	(1)
2	17	64	19	AV1+.50	AVB WEAR	(1)
2	17	64	28	AV2-.73	AVB WEAR	(1)
2	17	64	21	AV3-.55	AVB WEAR	(1)
2	18	42	19	AV2+.00	AVB WEAR	(1)
2	18	72	19	AV3+.00	AVB WEAR	(1)
2	18	89	22	C01+.03	C/L WASTAGE	(1)
2	19	28	21	AV1-.14	AVB WEAR	(1)
2	20	34	<40	HTS+1.38	DIST. BC SIG.	(1)
2	21	53	PI	H05+.03	ODSCC TSP	(1)
2	22	41	23	AV2+.00	AVB WEAR	(1)
2	22	73	PI	H05-.03	ODSCC TSP	(1)
2	23	69	31	AV2+.00	AVB WEAR	(1)
2	23	69	27	AV3+.00	AVB WEAR	(1)
2	24	37	<40	HTS+1.32	DIST. BC SIG.	(1)
2	24	61	30	AV2-.08	AVB WEAR	(1)
2	24	63	31	AV2+.00	AVB WEAR	(1)
2	24	82	PI	H02+.08	ODSCC TSP	(1)
2	24	87	PI	H01+.03	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	26	21	PI	H04-.03	ODSCC TSP	(1)
2	26	23	PI	C06+.00	ODSCC TSP	(1)
2	26	70	25	AV3+.25	AVB WEAR	(1)
2	27	65	28	AV2+.00	AVB WEAR	(1)
2	27	65	28	AV3+.00	AVB WEAR	(1)
2	27	84	PI	H01+.03	ODSCC TSP	(1)
2	28	69	PI	H02+.03	ODSCC TSP	(1)
2	29	16	PI	H01+.05	ODSCC TSP	(1)
2	29	16	PI	H02+.05	ODSCC TSP	(1)
2	29	32	30	AV2+.06	AVB WEAR	(1)
2	29	32	23	AV3-.29	AVB WEAR	(1)
2	29	32	24	AV4-.88	AVB WEAR	(1)
2	29	37	18	AV2+.00	AVB WEAR	(1)
2	29	37	17	AV3+.00	AVB WEAR	(1)
2	29	39	15	AV2+.00	AVB WEAR	(1)
2	29	39	20	AV3+.00	AVB WEAR	(1)
2	29	42	30	AV1-.22	AVB WEAR	(1)
2	29	42	31	AV2-.17	AVB WEAR	(1)
2	29	42	39	AV3+.03	AVB WEAR	(1)
2	29	42	15	AV4-.08	AVB WEAR	(1)
2	30	70	PI	H01+.05	ODSCC TSP	(1)
2	31	17	PI	H04+.05	ODSCC TSP	(1)
2	31	70	PI	H01+.08	ODSCC TSP	(1)
2	32	20	PI	H01+.05	ODSCC TSP	(1)
2	32	20	PI	H02+.03	ODSCC TSP	(1)
2	32	20	PI	H03-.05	ODSCC TSP	(1)
2	32	54	20	AV2+.00	AVB WEAR	PLUG
2	32	54	42	AV3+.00	AVB WEAR	PLUG
2	32	56	22	AV1-.08	AVB WEAR	(1)
2	32	56	26	AV2-.14	AVB WEAR	(1)
2	32	62	18	AV2+.22	AVB WEAR	(1)
2	32	62	22	AV3+.00	AVB WEAR	(1)
2	32	79	48	C01-.27	C/L WASTAGE	PLUG
2	33	49	23	AV1-.17	AVB WEAR	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	33	49	31	AV2-.08	AVB WEAR	(1)
2	33	49	35	AV3-.08	AVB WEAR	(1)
2	33	49	17	AV4-.11	AVB WEAR	(1)
2	33	62	19	AV3+.28	AVB WEAR	(1)
2	34	17	13	C01-.19	C/L WASTAGE	(1)
2	34	63	20	AV1+.00	AVB WEAR	PLUG
2	34	63	40	AV2+.00	AVB WEAR	PLUG
2	34	63	21	AV3+.00	AVB WEAR	PLUG
2	35	55	PI	H02+.03	ODSCC TSP	(1)
2	36	18	29	C01+.00	C/L WASTAGE	(1)
2	36	42	PI	H02+.05	ODSCC TSP	(1)
2	36	71	PI	H01+.06	ODSCC TSP	(1)
2	37	20	PI	H01+.03	ODSCC TSP	(1)
2	37	21	14	C01+.06	C/L WASTAGE	(1)
2	38	22	24	C03+.05	C/L WASTAGE	(1)
2	38	24	23	C01+.14	C/L WASTAGE	(1)
2	38	43	14	AV3-.19	AVB WEAR	(1)
2	38	43	17	AV4-.08	AVB WEAR	(1)
2	38	43	16	AV4-.13	AVB WEAR	(1)
2	38	45	PI	H02+.05	ODSCC TSP	(1)
2	38	45	PI	H03+.05	ODSCC TSP	(1)
2	38	46	20	AV3+.00	AVB WEAR	(1)
2	38	46	22	AV4+.00	AVB WEAR	(1)
2	39	49	16	AV3-.22	AVB WEAR	(1)
2	39	49	18	AV4-.19	AVB WEAR	(1)
2	42	31	30	C01-.13	C/L WASTAGE	(1)
2	42	39	PI	H03+.05	ODSCC TSP	(1)
2	42	64	32	C01+.25	C/L WASTAGE	(1)
2	42	66	17	C01+.14	C/L WASTAGE	(1)
2	43	49	PI	H02+.05	ODSCC TSP	(1)
2	43	63	26	C01+.00	C/L WASTAGE	(1)
2	44	33	13	C01+.13	C/L WASTAGE	(1)
2	44	34	PI	H01+.05	ODSCC TSP	(1)
2	44	36	PI	H04+.00	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
2	46	48	17	C01+.19	C/L WASTAGE	(1)
This sample's results have been classified as Category C-2						
Top of Tubesheet RPC Expansion						
2	13	84	SAI	HTS-.01	PWSCC HTS	PLUG
2	18	80	SAI	HTS-.01	PWSCC HTS	PLUG
This sample's results have been classified as Category C-2						
Cold Leg Bobbin Coil Expansion						
2	3	25	PI	C01+.00	ODSCC TSP	(1)
2	4	19	PI	C02+.03	ODSCC TSP	(1)
2	4	20	PI	C02+.05	ODSCC TSP	(1)
2	4	21	PI	C02+.03	ODSCC TSP	(1)
2	4	23	PI	C02+.00	ODSCC TSP (pull)	PLUG (tube pull)
2	4	24	PI	C02+.08	ODSCC TSP	(1)
2	6	10	PI	C02+.08	ODSCC TSP	(1)
2	7	22	PI	C01-.03	ODSCC TSP	(1)
2	8	8	PI	C04-.03	ODSCC TSP	(1)
This sample's results have been classified as Category C-2						

(1) Retest Future Outage

(2) None Required

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
3	1	2	SAI	H07+7.74	PWSCC U-BEND	PLUG
3	1	27	SAI	H07+3.69	PWSCC U-BEND	PLUG
3	1	26	SAI	H07+4.28	PWSCC U-BEND	PLUG
3	1	29	MAI	H07+3.85	PWSCC U-BEND	PLUG
3	1	38	SAI	H07+6.41	PWSCC U-BEND	PLUG
3	1	50	SAI	H07+2.67	PWSCC U-BEND	PLUG
3	1	59	SAI	H07+7.48	PWSCC U-BEND	PLUG
3	2	16	PI	H01-.03	ODSCC TSP	(1)
3	2	39	PI	H02-.05	ODSCC TSP	(1)
3	2	44	PI	C01+.00	ODSCC TSP	(1)
3	2	83	PI	H06+.06	ODSCC TSP	(1)
3	3	2	PI	H01+.00	ODSCC TSP	(1)
3	4	50	PI	H05+.03	ODSCC TSP	(1)
3	4	82	PI	H02-.03	ODSCC TSP	(1)
3	5	1	22	C01+.66	C/L WASTAGE	(1)
3	5	1	PI	H02-.03	ODSCC TSP	(1)
3	5	6	PI	C01+.05	ODSCC TSP	(1)
3	5	8	PI	C01+.03	ODSCC TSP	(1)
3	5	17	PI	H02-.05	ODSCC TSP	(1)
3	5	19	PI	H01+.00	ODSCC TSP	(1)
3	5	45	<40	HTS+1.23	DIST. BC SIG.	(1)
3	5	51	PI	H05+.00	ODSCC TSP	(1)
3	6	48	PI	H01+.03	ODSCC TSP	(1)
3	7	71	PI	H02-.03	ODSCC TSP	(1)
3	7	72	PI	H02+.00	ODSCC TSP	(1)
3	8	2	56	C01+.11	C/L WASTAGE	PLUG
3	8	14	96	HTS-1.36	PWSCC HTS	PLUG
3	8	14	SAI	HTS-1.69	PWSCC HTS	PLUG
3	8	56	PI	H01+.08	ODSCC TSP	(1)
3	8	57	PI	H04-.03	ODSCC TSP	(1)
3	8	58	PI	H01+.03	ODSCC TSP	(1)
3	8	60	SAI	H01+.00	ODSCC TSP (pull)	PLUG (tube pull)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	8	60	PI	H01-.03	ODSCC TSP (pull)	PLUG (tube pull)
3	8	69	PI	H01+.03	ODSCC TSP	(1)
3	9	2	PI	H01-.08	ODSCC TSP	(1)
3	9	14	PI	C01+.03	ODSCC TSP	(1)
3	9	33	<40	HTS+1.55	DIST. BC SIG.	(1)
3	9	36	<40	HTS+1.64	DIST. BC SIG.	(1)
3	9	42	<40	HTS+1.28	DIST. BC SIG.	(1)
3	9	48	PI	H01+.03	ODSCC TSP	(1)
3	9	51	PI	H01+.00	ODSCC TSP	(1)
3	9	68	<40	HTS+1.48	DIST. BC SIG.	(1)
3	10	2	PI	H04+.03	ODSCC TSP	(1)
3	10	5	PI	H01+.14	ODSCC TSP	(1)
3	10	20	PI	C01-.03	ODSCC TSP	(1)
3	10	58	<40	HTS+1.32	DIST. BC SIG.	(1)
3	10	60	<40	HTS+1.39	DIST. BC SIG.	(1)
3	10	61	<40	HTS+1.57	DIST. BC SIG.	(1)
3	10	62	PI	H01+.00	ODSCC TSP	(1)
3	10	93	19	C03+.00	C/L WASTAGE	(1)
3	10	93	19	C03+.05	C/L WASTAGE	(1)
3	11	2	32	C01-.08	C/L WASTAGE	(1)
3	11	16	PI	H06+.03	ODSCC TSP	(1)
3	12	12	PI	H01+.06	ODSCC TSP	(1)
3	12	46	<40	HTS+1.17	DIST. BC SIG.	(1)
3	12	50	SAI	HTS-1.37	PWSCC HTS	PLUG
3	13	3	PI	H02+.03	ODSCC TSP	(1)
3	13	11	PI	C07+.05	ODSCC TSP	(1)
3	13	31	PI	H01+.03	ODSCC TSP	(1)
3	13	46	<40	HTS+1.47	DIST. BC SIG.	(1)
3	13	53	PI	H01+.00	ODSCC TSP	(1)
3	14	3	13	C01-.19	C/L WASTAGE	(1)
3	14	14	PI	H01+.19	ODSCC TSP	(1)
3	14	20	PI	H02-.03	ODSCC TSP	(1)
3	14	56	PI	H02+.06	ODSCC TSP	(1)
3	15	3	PI	H01+.05	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	15	3	PI	H02+.05	ODSCC TSP	(1)
3	15	15	PI	H01+.08	ODSCC TSP	(1)
3	16	4	PI	H02+.05	ODSCC TSP	(1)
3	16	54	PI	H01+.08	ODSCC TSP	(1)
3	16	68	SAI	HTS-1.76	PWSCC HTS	PLUG
3	16	81	PI	C01+.03	ODSCC TSP	(1)
3	17	22	PI	H01+.14	ODSCC TSP	(1)
3	17	81	PI	C01+.05	ODSCC TSP	(1)
3	18	18	PI	H01+.05	ODSCC TSP	(1)
3	18	21	PI	H01+.11	ODSCC TSP	(1)
3	18	30	20	AV2+.00	AVB WEAR	(1)
3	18	35	PI	H01+.08	ODSCC TSP	(1)
3	18	38	PI	H01-.03	ODSCC TSP	(1)
3	18	49	PI	H01+.03	ODSCC TSP	(1)
3	18	65	<40	HTS+1.27	DIST. BC SIG.	(1)
3	19	14	PI	H02+.19	ODSCC TSP	(1)
3	19	64	27	AV2+.00	AVB WEAR	(1)
3	19	79	PI	H02+.05	ODSCC TSP	(1)
3	20	12	PI	H01+.11	ODSCC TSP	(1)
3	20	28	PI	H01+.22	ODSCC TSP	(1)
3	21	24	PI	H01+.08	ODSCC TSP	(1)
3	21	51	<40	HTS+1.39	DIST. BC SIG.	(1)
3	21	84	PI	H04+.03	ODSCC TSP	(1)
3	22	88	PI	H03+.14	ODSCC TSP	(1)
3	23	33	SAI	HTS-1.21	PWSCC HTS	PLUG
3	24	12	PI	H01+.05	ODSCC TSP	(1)
3	24	29	PI	H01+.05	ODSCC TSP	(1)
3	25	9	PI	C01+.03	ODSCC TSP	(1)
3	26	9	PI	H01+.05	ODSCC TSP	(1)
3	26	35	PI	H01+.03	ODSCC TSP	(1)
3	26	80	PI	H05+.05	ODSCC TSP	(1)
3	27	26	PI	H01+.14	ODSCC TSP	(1)
3	27	26	PI	H02+.11	ODSCC TSP	(1)
3	27	30	PI	H02+.08	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	27	50	<40	HTS+.87	DIST. BC SIG.	(1)
3	28	45	17	AV1+.00	AVB WEAR	(1)
3	28	45	18	AV2+.00	AVB WEAR	(1)
3	28	45	20	AV3+.00	AVB WEAR	(1)
3	29	81	PI	H02+.16	ODSCC TSP	(1)
3	30	23	PI	H01+.14	ODSCC TSP	(1)
3	31	81	PI	H05+.08	ODSCC TSP	(1)
3	32	24	25	AV1+.00	AVB WEAR	(1)
3	32	40	19	AV3+.00	AVB WEAR	(1)
3	32	78	PI	H04+.03	ODSCC TSP	(1)
3	32	78	PI	H05+.06	ODSCC TSP	(1)
3	32	79	PI	H05+.08	ODSCC TSP	(1)
3	32	79	PI	H06+.03	ODSCC TSP	(1)
3	33	21	PI	H01+.16	ODSCC TSP	(1)
3	33	25	PI	H04+.08	ODSCC TSP	(1)
3	33	40	PI	H01+.05	ODSCC TSP	(1)
3	33	61	13	AV1+.00	AVB WEAR	(1)
3	33	61	15	AV3+.00	AVB WEAR	(1)
3	33	79	30	C01-.08	C/L WASTAGE	(1)
3	34	16	15	C01-.19	C/L WASTAGE	(1)
3	34	19	PI	H02-.03	ODSCC TSP	(1)
3	34	21	PI	H01+.14	ODSCC TSP	(1)
3	34	43	32	AV2+.00	AVB WEAR	(1)
3	34	43	38	AV3+.00	AVB WEAR	(1)
3	34	43	21	AV4+.00	AVB WEAR	(1)
3	34	72	PI	H02+.05	ODSCC TSP	(1)
3	34	78	22	C01+.08	C/L WASTAGE	(1)
3	35	17	19	C01-.47	C/L WASTAGE	(1)
3	35	38	PI	C02+.03	ODSCC TSP	(1)
3	35	39	25	AV1-.08	AVB WEAR	(1)
3	35	76	PI	H05+.00	ODSCC TSP	(1)
3	35	76	PI	H06+.00	ODSCC TSP	(1)
3	37	33	PI	H04+.03	ODSCC TSP	(1)
3	38	22	PI	H01+.14	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 **Date: *02-Jul-96***

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
3	38	40	18	AV3+.00	AVB WEAR	(1)
3	38	40	20	AV4+.00	AVB WEAR	(1)
3	39	68	PI	H04+.08	ODSCC TSP	(1)
3	40	24	PI	H02-.03	ODSCC TSP	(1)
3	40	25	PI	H01+.06	ODSCC TSP	(1)
3	40	64	PI	H03+.03	ODSCC TSP	(1)
3	42	33	PI	H01+.00	ODSCC TSP	(1)
3	43	44	PI	H04+.08	ODSCC TSP	(1)
3	44	34	PI	H01+.05	ODSCC TSP	(1)
3	46	47	PI	H05-.03	ODSCC TSP	(1)

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

Top of Tubesheet RPC Expansion

No Indications

This sample's results have been classified as Category C-1

(1) Retest Future Outage

(2) None Required

TABLE 2

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

Outage: SQN Unit 2 Cycle 7 **Date:** ***02-Jul-96***

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
INITIAL SAMPLE						
4	1	15	SAI	H07+6.90	PWSCC U-BEND	PLUG
4	1	17	SAI	H07+6.09	PWSCC U-BEND	PLUG
4	1	17	SAI	H07+6.77	PWSCC U-BEND	PLUG
4	1	19	SAI	H07+6.64	PWSCC U-BEND	PLUG
4	1	23	SOI	H07+6.48	PWSCC U-BEND	PLUG
4	1	94	<40	H02-.38	DIST. BC SIG.	(1)
4	1	94	31	HTS+17.56	FLBD WEAR	(1)
4	2	9	PI	C04-.03	ODSCC TSP	(1)
4	2	13	SAI	HTS-.02	PWSCC HTS	PLUG
4	2	15	PI	C06+.03	ODSCC TSP	(1)
4	2	37	PI	H02+.03	ODSCC TSP	(1)
4	2	40	PI	H01+.05	ODSCC TSP	(1)
4	2	53	PI	H01+.11	ODSCC TSP	(1)
4	2	55	PI	H01+.11	ODSCC TSP	(1)
4	2	58	PI	H02-.03	ODSCC TSP	(1)
4	2	61	PI	H02+.08	ODSCC TSP	(1)
4	2	67	PI	H01+.05	ODSCC TSP	(1)
4	2	76	PI	H01+.05	ODSCC TSP	(1)
4	3	8	PI	H02+.00	ODSCC TSP	(1)
4	3	26	PI	C02-.03	ODSCC TSP	(1)
4	3	71	PI	H02-.03	ODSCC TSP	(1)
4	3	72	PI	H01-.03	ODSCC TSP	(1)
4	4	22	PI	H02+.08	ODSCC TSP	(1)
4	4	87	PI	H01+.03	ODSCC TSP	(1)
4	4	89	PI	H03+.03	ODSCC TSP	(1)
4	4	91	PI	H01+.00	ODSCC TSP	(1)
4	5	1	PI	H01+.08	ODSCC TSP	(1)
4	5	12	PI	H02+.00	ODSCC TSP	(1)
4	5	42	PI	H01+.03	ODSCC TSP	(1)
4	5	46	PI	H01-.05	ODSCC TSP	(1)
4	5	51	PI	H06+.00	ODSCC TSP	(1)
4	5	53	PI	H01+.11	ODSCC TSP	(1)

TABLE 2

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	5	84	PI	H01+.08	ODSCC TSP	(1)
4	5	91	PI	H01+.00	ODSCC TSP	(1)
4	6	37	PI	H01+.05	ODSCC TSP	(1)
4	6	45	PI	H01+.05	ODSCC TSP	(1)
4	6	84	PI	H01+.08	ODSCC TSP	(1)
4	7	50	SAI	HTS-.10	PWSCC HTS	PLUG
4	7	51	PI	H01+.05	ODSCC TSP	(1)
4	8	3	PI	H03+.03	ODSCC TSP	(1)
4	8	8	PI	H02-.03	ODSCC TSP	(1)
4	8	35	PI	H01-.03	ODSCC TSP	(1)
4	8	37	PI	H01+.08	ODSCC TSP	(1)
4	8	42	PI	H01+.03	ODSCC TSP	(1)
4	8	52	PI	H01+.00	ODSCC TSP	(1)
4	8	53	PI	H01+.05	ODSCC TSP	(1)
4	8	55	PI	H01+.11	ODSCC TSP	(1)
4	8	59	PI	H01+.08	ODSCC TSP	(1)
4	8	60	PI	H01-.03	ODSCC TSP	(1)
4	8	80	PI	H01-.03	ODSCC TSP	(1)
4	8	85	PI	H01-.03	ODSCC TSP	(1)
4	8	86	PI	H01-.03	ODSCC TSP	(1)
4	8	92	PI	H01+.00	ODSCC TSP	(1)
4	8	92	PI	H02+.03	ODSCC TSP	(1)
4	9	38	PI	H01+.00	ODSCC TSP	(1)
4	9	43	PI	H01+.00	ODSCC TSP	(1)
4	9	50	PI	H01+.11	ODSCC TSP	(1)
4	9	74	PI	H05+.00	ODSCC TSP	(1)
4	11	3	14	C01-.17	C/L WASTAGE	(1)
4	11	53	<40	HTS+.99	DIST. BC SIG.	(1)
4	11	65	<40	HTS+2.04	DIST. BC SIG.	(1)
4	11	67	<40	HTS+1.63	DIST. BC SIG.	(1)
4	11	85	PI	H05+.16	ODSCC TSP	(1)
4	12	26	PI	H02+.11	ODSCC TSP	(1)
4	12	32	PI	H01+.11	ODSCC TSP	(1)
4	12	41	PI	H01+.14	ODSCC TSP	(1)

TABLE 2

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	12	43	PI	H01+.16	ODSCC TSP	(1)
4	12	45	PI	H01+.11	ODSCC TSP	(1)
4	12	59	PI	H01+.11	ODSCC TSP	(1)
4	12	61	PI	H01+.11	ODSCC TSP	(1)
4	12	64	PI	H01+.05	ODSCC TSP	(1)
4	12	67	<40	HTS+.94	DIST. BC SIG.	(1)
4	12	67	<40	HTS+1.50	DIST. BC SIG.	(1)
4	12	72	PI	H01+.00	ODSCC TSP	(1)
4	12	83	PI	H01+.08	ODSCC TSP	(1)
4	13	38	PI	H01+.14	ODSCC TSP	(1)
4	13	45	PI	H01+.11	ODSCC TSP	(1)
4	13	47	PI	H03+.14	ODSCC TSP	(1)
4	13	48	PI	H01+.08	ODSCC TSP	(1)
4	13	52	PI	H01+.16	ODSCC TSP	(1)
4	13	53	PI	H01+.11	ODSCC TSP	(1)
4	14	54	<40	HTS+1.07	DIST. BC SIG.	(1)
4	14	57	PI	H01+.06	ODSCC TSP	(1)
4	14	88	PI	H01+.11	ODSCC TSP	(1)
4	14	92	PI	H01+.08	ODSCC TSP	(1)
4	15	48	PI	H01+.05	ODSCC TSP	(1)
4	15	50	PI	H01+.03	ODSCC TSP	(1)
4	15	51	PI	H01+.11	ODSCC TSP	(1)
4	15	52	PI	H01+.11	ODSCC TSP	(1)
4	15	53	PI	H01+.06	ODSCC TSP	(1)
4	15	54	PI	H01+.22	ODSCC TSP	(1)
4	15	57	<40	HTS+1.73	DIST. BC SIG.	(1)
4	15	62	PI	H01+.08	ODSCC TSP	(1)
4	15	65	PI	H01+.17	ODSCC TSP	(1)
4	17	20	PI	H01+.22	ODSCC TSP	(1)
4	17	27	PI	H01+.22	ODSCC TSP	(1)
4	17	55	PI	H01+.14	ODSCC TSP	(1)
4	17	87	PI	H01+.08	ODSCC TSP	(1)
4	18	6	PI	H02+.11	ODSCC TSP	(1)
4	18	32	PI	C05-.11	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	18	33	PI	H05+.14	ODSCC TSP	(1)
4	18	54	PI	H01+.08	ODSCC TSP	(1)
4	18	61	PI	H01+.08	ODSCC TSP	(1)
4	20	45	PI	H01+.08	ODSCC TSP	(1)
4	20	47	PI	H02+.08	ODSCC TSP	(1)
4	20	48	PI	H01+.03	ODSCC TSP	(1)
4	20	50	PI	H01+.08	ODSCC TSP	(1)
4	20	51	PI	H01+.05	ODSCC TSP	(1)
4	20	56	PI	H01+.16	ODSCC TSP	(1)
4	20	58	PI	H01+.08	ODSCC TSP	(1)
4	20	59	PI	H01+.05	ODSCC TSP	(1)
4	20	60	PI	H01+.14	ODSCC TSP	(1)
4	20	63	PI	H01+.08	ODSCC TSP	(1)
4	20	69	PI	H01+.11	ODSCC TSP	(1)
4	21	6	PI	H04+.08	ODSCC TSP	(1)
4	21	15	PI	H06+.08	ODSCC TSP	(1)
4	21	19	PI	C05-.08	ODSCC TSP	(1)
4	22	15	PI	H02+.08	ODSCC TSP	(1)
4	22	17	PI	C04-.08	ODSCC TSP	(1)
4	22	17	PI	C05-.14	ODSCC TSP	(1)
4	22	17	PI	H02+.14	ODSCC TSP	(1)
4	22	59	PI	H01+.05	ODSCC TSP	(1)
4	22	70	PI	H01+.14	ODSCC TSP	(1)
4	22	71	PI	H03+.14	ODSCC TSP	(1)
4	23	64	PI	H01+.11	ODSCC TSP	(1)
4	23	65	PI	H02+.14	ODSCC TSP	(1)
4	23	69	PI	H02+.25	ODSCC TSP	(1)
4	23	71	PI	H01+.11	ODSCC TSP	(1)
4	23	73	PI	H02+.11	ODSCC TSP	(1)
4	24	22	PI	H03+.09	ODSCC TSP	(1)
4	25	57	PI	H02+.05	ODSCC TSP	(1)
4	25	67	PI	H04+.06	ODSCC TSP	(1)
4	26	15	PI	H02+.08	ODSCC TSP	(1)
4	26	69	PI	H01+.11	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	26	71	PI	H01+.11	ODSCC TSP	(1)
4	26	86	PI	H02+.11	ODSCC TSP	(1)
4	27	63	PI	H01+.08	ODSCC TSP	(1)
4	27	70	PI	H01+.11	ODSCC TSP	(1)
4	27	71	PI	H01+.11	ODSCC TSP	(1)
4	27	72	PI	H02+.08	ODSCC TSP	(1)
4	27	72	PI	H03+.11	ODSCC TSP	(1)
4	27	75	PI	H02+.16	ODSCC TSP	(1)
4	27	76	PI	H01+.03	ODSCC TSP	(1)
4	27	77	PI	H01+.11	ODSCC TSP	(1)
4	27	77	PI	H02+.14	ODSCC TSP	(1)
4	27	77	PI	H03+.16	ODSCC TSP	(1)
4	27	78	PI	H02+.08	ODSCC TSP	(1)
4	27	79	PI	H02+.16	ODSCC TSP	(1)
4	27	80	PI	H02+.08	ODSCC TSP	(1)
4	27	83	PI	H01+.11	ODSCC TSP	(1)
4	28	18	PI	H02+.06	ODSCC TSP	(1)
4	28	62	PI	H02+.08	ODSCC TSP	(1)
4	28	63	PI	H02+.11	ODSCC TSP	(1)
4	28	67	MAI	H01+.00	ODSCC TSP	(1)
4	28	67	MAI	H01+.00	ODSCC TSP	(1)
4	28	67	PI	H01+.11	ODSCC TSP	(1)
4	28	67	MAI	H01-.07	ODSCC TSP	(1)
4	28	68	PI	H01+.06	ODSCC TSP	(1)
4	28	68	PI	H02+.11	ODSCC TSP	(1)
4	28	70	PI	H01+.16	ODSCC TSP	(1)
4	28	70	PI	H02+.14	ODSCC TSP	(1)
4	28	72	PI	H01+.11	ODSCC TSP	(1)
4	28	72	PI	H02+.19	ODSCC TSP	(1)
4	28	77	PI	H01+.08	ODSCC TSP	(1)
4	28	78	PI	H01+.16	ODSCC TSP	(1)
4	28	79	PI	H03+.16	ODSCC TSP	(1)
4	28	81	PI	H02+.08	ODSCC TSP	(1)
4	29	18	PI	H07+.06	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	29	51	PI	H01+.11	ODSCC TSP	(1)
4	29	56	PI	H06+.22	ODSCC TSP	(1)
4	29	67	21	AV1+1.54	AVB WEAR	(1)
4	29	67	28	AV3+.03	AVB WEAR	(1)
4	29	67	18	AV4-.14	AVB WEAR	(1)
4	30	80	PI	C05-.08	ODSCC TSP	(1)
4	31	54	PI	H01+.16	ODSCC TSP	(1)
4	31	72	PI	H01+.11	ODSCC TSP	(1)
4	31	79	PI	C05-.08	ODSCC TSP	(1)
4	31	82	PI	C04-.05	ODSCC TSP	(1)
4	32	41	12	AV2+.33	AVB WEAR	(1)
4	32	41	11	AV3+.00	AVB WEAR	(1)
4	32	65	PI	H02+.14	ODSCC TSP	(1)
4	32	70	PI	H02+.16	ODSCC TSP	(1)
4	34	18	PI	H06+.14	ODSCC TSP	(1)
4	35	55	14	AV1+.00	AVB WEAR	(1)
4	36	57	PI	H02+.22	ODSCC TSP	(1)
4	36	62	PI	H02+.05	ODSCC TSP	(1)
4	36	65	PI	H01+.11	ODSCC TSP	(1)
4	36	68	PI	H02+.11	ODSCC TSP	(1)
4	37	19	11	C01-.16	C/L WASTAGE	(1)
4	37	62	PI	H04+.08	ODSCC TSP	(1)
4	37	63	PI	H01+.08	ODSCC TSP	(1)
4	38	21	PI	H06+.11	ODSCC TSP	(1)
4	38	26	PI	H02+.11	ODSCC TSP	(1)
4	38	44	19	AV3-.11	AVB WEAR	(1)
4	38	47	19	AV3+.00	AVB WEAR	(1)
4	38	47	16	AV4+.00	AVB WEAR	(1)
4	38	49	17	AV3+.00	AVB WEAR	(1)
4	38	52	22	AV3+.20	AVB WEAR	(1)
4	38	52	26	AV4+.25	AVB WEAR	(1)
4	38	65	16	AV1-.28	AVB WEAR	(1)
4	38	65	17	AV2-.08	AVB WEAR	(1)
4	38	74	PI	H04+.08	ODSCC TSP	(1)

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

Outage: SQN Unit 2 Cycle 7 Date: *02-Jul-96*

SG	ROW	COL	IND	LOCATION	CHARACTERIZATION	RESOLUTION
4	40	49	PI	H02+.11	ODSCC TSP	(1)
4	43	35	15	C02+.05	C/L WASTAGE	(1)
4	43	61	39	C02-.14	C/L WASTAGE	(1)
4	44	58	PI	H06+.11	ODSCC TSP	(1)
4	44	59	PI	H01+.11	ODSCC TSP	(1)
4	44	61	29	C03+.22	C/L WASTAGE	(1)
4	45	54	14	C02+.08	C/L WASTAGE	(1)
4	45	57	27	C02-.14	C/L WASTAGE	(1)

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

Top of Tubesheet RPC Expansion

No Indications

This sample's results have been classified as Category C-1

(1) Retest Future Outage

(2) None Required

TABLE 2

Location Nomenclature for SQN

Notation	Description
HTE	Tube end - hot leg
HTS	Top of tubesheet - hot leg
H01	First support plate - hot leg
H02	Second support plate - hot leg
H03	Third support plate - hot leg
H04	Fourth support plate - hot leg
H05	Fifth support plate - hot leg
H06	Sixth support plate - hot leg
H07	Seventh support plate - hot leg
AV1	First anti-vibration bar above H07
AV2	Second anti-vibration bar above H07
AV3	Second anti-vibration bar above C07
AV4	First anti-vibration bar above C07
C07	Seventh support plate - cold leg
C06	Sixth support plate - cold leg
C05	Fifth support plate - cold leg
C04	Fourth support plate - cold leg
C03	Third support plate - cold leg
C02	Second support plate - cold leg
C01	First support plate - cold leg
CTS	Top of tubesheet - cold leg
CTE	Tube end - cold leg

Indication and Characterization Nomenclature

Notation	Description
AVB	Anti-Vibration Bar
C/L	Cold Leg
Dist. BC Sig.	Distorted Bobbin Coil Signal
FLBD	Flow Lane Blocking Device
MAI	Multiple Axial Indications
ODSCC	Outside Diameter Stress Corrosion Cracking
PI	Potential Indication (ODSCC at TSPs)
PWSCC	Primary Water Stress Corrosion Cracking
SAI	Single Axial Indication
SOI	Single Oblique Indication
TSP	Tube Support Plate

ALTERNATE PLUGGING CRITERIA RESULTS

A report in accordance with Technical Specification Change 95-23 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 2. The Westinghouse report is Attachment 1.

LOW ROW U-BEND INDICATION RESULTS

Low row U-bend PWSCC was detected with RPC examinations during the Unit 2 Cycle 7 outage. Seventeen tubes were removed from service during this inspection. Historical data review of these indications was performed to determine growth rate information in support of structural integrity analysis. All the row 1 indications detected during the Unit 2 Cycle 7 inspection were affected by permeability changes in the tubing which coincided with the flaw location in the previous inspection. It was determined that non-magnetically bias probes were used during the Unit 2 Cycle 6 inspection. Westinghouse performed the structural integrity analysis of the three largest indications (See Attachment 2). TVA has reviewed the results of the analysis and concurs with the conclusion that structural integrity was maintained during cycle 7 operation. The one row 2 indication detected during the Unit 2 Cycle 7 outage was not believed to be crack-like but was conservatively plugged.

CONCLUSIONS

The NDE testing completed on the SQN Unit 2 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 95-23.

Steam Generator Chemical Cleaning was implemented during the Unit 2 Cycle 7 outage as an ameliorative measure for ODSCC at non-dented tube support plate intersections to prevent future incidence of ODSCC at all tube locations.

Attachment 1

WESTINGHOUSE PROPRIETARY CLASS 3

SG-96-08-010

SEQUOYAH UNIT - 2

CYCLE 8 ALTERNATE PLUGGING CRITERIA
90 DAY REPORT

August 1996

Westinghouse Electric Corporation
Energy Systems Business Unit
Nuclear Services Division
P.O. Box 158
Madison, Pennsylvania 15663-0158

WESTINGHOUSE PROPRIETARY CLASS 3

SG-96-08-010

SEQUOYAH UNIT - 2

CYCLE 8 ALTERNATE PLUGGING CRITERIA 90 DAY REPORT

August 1996

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SEQUOYAH UNIT - 2
CYCLE 8 ALTERNATE PLUGGING CRITERIA
90 DAY REPORT

1.0 INTRODUCTION

This report provides an evaluation of the Sequoyah Unit-2 steam generator (SG) eddy current data at tube support plates (TSPs) at End of Cycle 7 (EOC-7), including Steam Line Break (SLB) leak rate and tube burst probability results, in support of the implementation of the Alternate Plugging Criteria (APC) for Cycle 8 operation 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 tube burst probabilities for Cycle 8 operation. The methodology used in these evaluations is in accordance with the plant-specific methodology for the Sequoyah Units 1 & 2 presented in Reference 9.2 as well as the generic methodology described in Reference 9.3.

The application of the TSP APC for the Sequoyah Unit-2 SGs involves a complete, 100% Eddy Current (EC) bobbin coil inspection of all TSP intersections in the tube bundles of all four SGs and plugging of TSP indications greater than 2 volts which are confirmed by a Rotating Pancake Coil (RPC) probe. RPC inspections are also 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.

This report also summarizes results from laboratory examination of tube specimens pulled from Sequoyah Unit-2 SGs during the EOC-7 outage.

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 Unit-2. SG 4 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.

A total of 366 axial outside diameter stress corrosion cracking (ODSCC) indications were found during the inspection in all four steam generators combined, of which only four indications had a voltage above one volt and none above two volts. Steam generator 4 had the largest number of indications found (170), and it is the limiting steam generator from the standpoint of SLB leak rate and tube burst probability. Twelve indications were inspected with a RPC probe and only two were confirmed. Two indications were located in tubes pulled to confirm ODSCC and, accordingly, 364 of the 366 indications were returned to service for Cycle 8. SG 4 with 170 indications had the largest number of indications reported at EOC-7 and all indications were returned to service for Cycle 8. SG 2 had the largest indication reported at EOC-7, 1.65 volts, and it was returned to service since it is below the 2 volt APC.

The bounding estimates for SLB leak rate and burst probability calculated using the measured EOC-7 voltage distributions are 0.07 gpm and 1.90×10^{-5}, respectively. These values were calculated for SG 4 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 the Cycle 7 growth rate distribution based on reevaluated voltages from EOC-6 and EOC-7 inspection bobbin data. Projections were made using both the NRC required constant probability of detection (POD) value of 0.6 as well as a voltage-dependent POD termed probability of prior cycle detection (POPCD). POPCD is established based on data from past IPC/APC inspections, and it takes into account newly initiated indications which is important for APC application. The POPCD distribution used here is established using data from 11 inspections conducted in 8 plants after 1992.

SG 4 was also found to be the limiting SG for Cycle 8 operation. SLB tube leak rate for SG 4 is projected to be 0.35 gpm at the EOC-8 conditions and the burst probability is projected to be 1.90×10^{-5}. These results, based on a conservative POD value of 0.6, are substantially lower than the Sequoyah Unit-2 APC allowable

limit for SLB leakage (3.7 gpm) and the NRC guideline of 1.0×10^{-2} for the burst probability.

Two tube segments, each containing the first and second TSP crevices, were pulled during this outage per the generic letter requirement. One tube segment is from the hot side of tube R8C60 in SG-3. It had a bobbin voltage of 1.1 volts at the first TSP intersection which was confirmed by RPC as an axial indication; the second TSP intersection was also inspected with RPC and found to be NDD. The other tube segment is from the cold side of tube R4C23 in SG-2; it had a bobbin voltage of 0.4 volt at the second TSP intersection and RPC inspection of both intersections did not show any flaws. The 1.1 volt indication on R8C60, TSP 1 was found to have a 60% maximum depth, 34% average depth and 0.523 inch length with a burst pressure of 9,434 psi. The 0.4 volt indication on R4C23, TSP 2 was found to have only a 2% depth indication. The indication at R8C60, TSP2 was found to have a 50% maximum depth, 20% average depth and 0.602 inch length with a burst pressure of 10.269 psi. Reevaluation of the field data for this indication yielded 0.2 volt. The crack morphology for the indications is axial ODSCC with cellular patches typical of the EPRI database for APC application. Incorporation of the Sequoyah Unit-2 data in the EPRI APC database would have negligible influence on the APC correlations (SLB structural limit, using 95%/95% lower tolerance limit material properties, increases by 0.1 volt, i.e., from 8.7 volts to 8.8 volts).

Chemical cleaning of all four steam generators was performed at this outage. The tube segments removed from SGs 2 and 3 were examined to assess the effects of chemical cleaning, if any, on surface deposits at the TSP intersections. The tubes were found to be very clean in the free span between TSP intersections. Deposits remained on the tube within the TSP; although the deposits were not as thick as frequently found in other plants without chemical cleaning. There were no other apparent effects of chemical cleaning relative to the application of the APC for ODSCC at TSP intersections.

3.0 SEQUOYAH UNIT-2 PULLED TUBE DATA

3.1 Sequoyah Unit-2 Pulled Tube Examination Results

3.1.1 Introduction

One cold leg tube (CL) segment (Tube R4C23) removed from SG 2 and one hot leg (HL) tube segment (Tube R8C60) from SG 3 of Sequoyah Unit-2 were examined at the Westinghouse Science and Technology Center primarily in support of alternative repair criteria (ARC) applications. The examination was conducted to characterize corrosion at the steam generator tube support plate (TSP) crevice locations. The tubes were selected to obtain a sampling of the indications observed in the spring 1996 field eddy current inspection to support Unit-2 application of the ARC for ODSCC at TSP intersections. The first and second TSP crevice regions (TSP 1 and TSP 2) of the tubes were removed. The TSP 1 region of HL Tube R8C60 and CL TSP 2 region of Tube R4C23 had original field eddy current calls of OD origin indications. The SGs were chemically cleaned prior to pulling the tubes.

After nondestructive laboratory examination by eddy current, ultrasonic testing, radiography, dimensional characterization and visual examination, the TSP 1 region of Tube R8C60, TSP 1 was leak tested at an elevated temperature. Subsequently, room temperature burst testing was conducted on the leak tested TSP 1 region, as well as the non-leak tested TSP 2 of Tube R8C60, non-leak tested TSP 1 and TSP 2 regions of Tube R4C23, and a free span (FS) section from each of the two tubes (R8C60 and R4C23). The two burst tested TSP specimens of Tube R8C60 were destructively examined using SEM fractography techniques to characterize corrosion. In addition, all four TSP burst tested specimens were further examined using metallography.

3.1.2 NDE Results

Visual inspection of the as-received tubes indicated no heavy deposits on the chemically cleaned tubes. The free span lengths of tubing were very clean while the TSP regions of tube R4C23 showed a very light deposit in some areas and the TSP regions of R8C60 showed relatively more and uniform deposit. However, there was no heavy deposit anywhere in the TSP or top of tubesheet regions of either tube.

Table 3-1 presents a summary of important field and laboratory NDE results. The eddy current data were reviewed, including re-evaluation of the field data, to reassess the voltages assigned to the indications and to assess the field no-

detectable-degradation (NDD) calls for detectability under laboratory analysis conditions. Results of a third analysis, with particular emphasis on the field NDD indications for incorporation into the ARC database, is discussed in Section 3.3. In general, field and laboratory eddy current inspections (bobbin probe, RPC and +Point probes) produced similar data for most of the regions examined.

For the TSP 2 of Tube R4C23, there was very little difference between the original field call and the field data re-evaluation. The re-evaluation of the TSP 1 showed the presence of a distorted indication with some characteristics similar to that of the TSP 2. This signal does not meet the normal calling criteria for an indication. The third analysis, discussed in Section 3.3, concludes that the TSP 1 indication is bobbin NDD. The 3-coil and +Point probes showed no indications for both the TSP regions. All indications were confined to the TSP crevice region. The laboratory, post-pull data of Tube R4C23 show little difference from the field data. In the case of the TSP 1, there was an approximately two-fold difference in the signal strength (voltage) present but the indication remains NDD by RPC inspection.

The re-evaluation of the field data for TSP 1 of Tube R8C60 resulted in only some minor differences in the RPC amplitudes measured. All indications were confined to the TSP crevice region. The laboratory data of the tubes exhibited some differences from the pre-pull data. The dents in the TSP 2 laboratory data are attributed to the tube pull process. In the case of the TSP 1, there was an approximately two-fold increase in the amplitude of the signal present in both the bobbin and RPC data. Also, there was a noticeable difference in the circumferential extent of the signals as measured by rotating probe techniques. These differences are attributed to the pulling process and possibly suggest some tearing of ligaments between microcracks. The TSP 2 exhibited some suggestion of degradation in the post-pull data not present in the field data. Given the presence of a tube pull-related dent, it is suggested that some tearing of ligaments between microcracks occurred at this location which enhanced the detection of the degradation.

The laboratory eddy current data for the TSP 1 region of Tube R8C60 indications had a considerable width in the RPC and +Point 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 both TSP regions of Tube R8C60 had indications. (Destructive examination also later found corrosion at the TSP crevice regions of this tube.)

Radiographic testing showed low level wall loss locally (pitting like indications) for the TSP 2 regions of Tubes R4C23 and R8C60, not confirmed during the

subsequent destructive testing. The radiographic indications probably were related to surface deposit variations.

All the indications were found on the OD surface of the tubes. No corrosion indications were noticed on the ID surface during the NDE examination or subsequent destructive testing.

3.1.3 Leak, Burst and Tensile Testing

The TSP 1 crevice region of tube R8C60, which had the largest original field eddy current indications, was leak tested at elevated temperature and pressure at conditions ranging from a simulated normal operating condition to a simulated steam line break condition. For the normal operating conditions, the primary side pressure and temperature were nominally 1950 psi and 620°F and the secondary side pressure and temperature were nominally 605 psi and 605°F. At the steam line break conditions, the primary side pressure and temperature were nominally 2780 psi and 618°F and the secondary side pressure and temperature were nominally 205 psi and 612°F. The tube did not develop any leak under these conditions.

All four pulled TSP crevice region 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. The TSP 1 crevice region of Tube R8C60, with relatively more degradation, was tested using a bladder and lubricated 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 of Tube R8C60 were within the crevice regions which had shown indications during laboratory NDE. The circumferential positions of the burst openings for this tube were close to the location of the deepest laboratory NDE indications. The bursts for R4C23 occurred above the TSP elevation indicating the likelihood of negligible degradation within the TSP. All TSP specimens burst at high pressures. The lowest burst pressure for the TSP crevice regions (Tube R8C60, TSP 1, the 1.1 volt field bobbin indication) was 9434 psi, 81% 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 cracking on both sides of the TSP burst openings of Tube R8C60. The corrosion was confined to the crevice regions. No cracking was visually identifiable on Tube R4C23 after the burst tests.

3.1.4 Destructive Examination Results

From post-burst test visual inspections, corrosion cracks were observed on the burst faces of both TSP specimens of Tube R8C60. However, all four TSP specimens were destructively examined. All specimens selected for destructive examination were metallographically examined for corrosion. The specimens with corrosion cracks on the burst faces were also evaluated by SEM fractography. The two free span sections taken one from each tube, selected for the reference burst pressure property test, had no degradation, as would be expected.

The burst fracture faces of the two TSP crevice region specimens from Tube R8C60 were opened for 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. Two ductile ligaments separating the microcracks were present on each burst opening macrocrack. All intergranular corrosion was confined within the crevice regions. For the TSP 1 region of Tube R8C60, the axial burst macrocrack had an average depth of 34% over a length of 0.523 inch with a maximum depth of 60% while the burst macrocrack of the TSP 2 region had an average depth of 21% over a length of 0.602 inch with a maximum depth of 50%.

Figures 3-1 to 3-4 present sketches of the TSP region burst openings. Figures 3-3 and 3-4 also show crack distributions on the OD surface of the tube found by visual (30X 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 corrosion was confined to the crevice regions.

Transverse metallographic sections were taken at the maximum width of the burst openings. These sections were in the mid TSP regions of Tube R8C60 and above the TSP regions of Tube R4C23. Additional transverse samples were taken in the mid TSP regions of Tube R4C23 to examine for corrosion cracking within the TSP elevation. Due to the complexities of the crack networks observed in the TSP regions of Tube R8C60, radial metallography was utilized, in addition to transverse metallography, to provide an overall understanding of the intergranular corrosion morphology. 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.

From the metallographic examinations conducted on the TSP 1 region of Tube R8C60, 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 TSP 1 of Tube R8C60 by radial metallography at a depth 2% below the OD surface. With progressive radial grinding, it was shown that the axial IGSCC became more dominant with depth while the ICC tended to disappear. Figure 3-6 provides the corrosion morphology at the TSP 2 region of Tube R8C60 at a depth 2% below the OD surface. This figure shows also the presence of ICC along with IGSCC. However, in the TSP 2 region, ICC was not as deep as in the TSP 1 region as shown in Table 3-4.

IGSCC morphology can be characterized by depth-to-width (D/W) ratios of the cracks. The widths are measured at mid-depths. IGA involvement has been characterized by three arbitrary categories of (D/W) ratios. D/W ratios greater than 20 are defined as having minor involvement, ratios between 3 and 20 as moderate, and ratios less than 3 as having significant IGA involvement. 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 TSP crevice regions of Tube R8C60 had similar crack densities and crack morphologies. The crack density was medium and the crack morphology was moderate, as measured by D/W ratios. The D/W ratio was 10 for the TSP 1 region and 6 for the TSP 2 region. The ratio for the TSP 2 region is less because the cracks were not as deep in as they were in the TSP 1 region even though the width of IGA involvement was the same. Table 3-4 presents a summary of the metallographic data. The TSP 1 and TSP 2 specimens of Tube R8C60 specimen had an estimated 45 and 40 cracks respectively over the tube circumference in the crevice region with the cracking concentrated near the burst fracture.

The TSP regions of Tube R4C23 did not show any corrosion cracks on the burst openings, the OD surface of the tube (Figures 3-1 and 3-2), or on the transverse metallographic sections taken at the center of burst section or in the TSP crevice region. (Table 3-4). Only minor isolated surface corrosion, ≤ 2% deep, was noticed at the tube OD, in the TSP crevice region.

3.1.5 Conclusions

Both the TSP crevice regions of Tube R8C60, hot leg from SG 3, 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. The depth of IGSCC and ICC was greater for the TSP 1 region as

compared to the TSP 2 region. All TSP region corrosion was confined to the crevice regions. The corrosion morphology was typical of pulled tubes within the EPRI database. The TSP crevice regions of Tube R4C23, cold leg from SG 2, did not show any corrosion cracking during burst or metallographic testing. Only minor isolated surface corrosion, ≤ 2% deep, was noticed at the tube OD, in the TSP-2 crevice region of R4C23.

Eddy current bobbin and other (RPC, +Point, Cecco) probe data correlated well with the corrosion distribution for the cracks of Tube R8C60. 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 (2 out of 2) and in the area extent and orientation of the corrosion.

The TSP crevice region burst pressures ranged from 9,434 to 12,378 psi. All burst pressures were well above safety guidelines of R.G. 1.121 and close to free span burst values, (i.e., those without corrosion) except for the TSP 1 region of Tube R8C60 which burst at 81% of its free span equivalent pressure. The burst pressure data were consistent with expectations and near the mean predictions for the alternative repair criteria burst pressure versus bobbin voltage correlation.

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. Depth profiling for R8C60, TSP 1 was performed prior to the destructive examination of the indication. The other, very low voltage indications were too small for depth sizing. The predicted depth profile is compared with the destructive examination results in this section.

Figure 3-7 shows the comparison of the +Point coil, eddy current depth profile with the destructive exam data for R8C60, TSP 1. The destructive exam length of 0.523" is somewhat longer than the NDE length of 0.38". The destructive exam results show a shallow tail of less than about 20% depth which was not detected by the +Point coil and depths for the lower end of the crack are underestimated. The average depth of 48.7% from NDE is larger than the 33.6% by destructive exam. Overall, the NDE results are conservative for calculating the burst pressure of the indication since the shallow tails of the crack do not contribute to the burst pressure. The burst pressure calculated from the destructive exam profile is 9,467 psi (effective or weak link crack length is 0.44" with an average depth of 39%) compared to the measured 9,434 psi. The burst pressure calculated from the NDE profile is 9,133 psi (weak link crack length is 0.35" with an average depth of 52%).

3.3 Sequoyah Unit-2 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 Unit-2 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 R8C60, TSP 1 and R4C23, TSP 2. An additional laboratory reevaluation of the field data was performed, particularly to assess the NDD calls for R8C60, TSP 2 and R4C23, TSP 1. Figures 3-8 to 3-11 show the bobbin analysis results for this reanalysis. 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 TSP 2 indication of R8C60 and the TSP 1 indication of R4C23 were found to be bobbin NDD in the field data. These indications are associated with maximum crack depths of 50% and no degradation, respectively, with an average depth of 20% for R8C60, TSP 2. The R8C60, TSP 2 indication was identified by reanalysis of the field data to be a 0.2 volt bobbin indication confirmed by +Point. The post-pull laboratory inspection identified the indication by all RPC, Cecco and UT probes although the bobbin data is masked by a dent from the tube pulling operations. The R4C23, TSP 1 indication is NDD by all pre and post pull analyses except one analyst evaluating the field and laboratory bobbin data. The bobbin analysis is shown in Figure 3-10 and shows no significant flaw response in the single frequency results and is typical of non-flawed mixed residuals found in field inspections. The bobbin response for TSP 2 of R4C23, which had only a 2% corrosion depth, has a more significant flaw like response at all frequencies even though the corrosion depth is expected to be too small to cause the flaw like bobbin response at TSP 2. For ARC applications, it is appropriate to consider TSP 1 to be NDD and TSP 2 to be a flaw indication.

The Sequoyah Unit-2 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. The area of the tubes near the top of the TSP were essentially free of deposits. 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 significantly affected by the cleaning operations since the changes in post-pull voltages are similar to that found for tubes without chemical cleaning.

3.3.2 Sequoyah Unit-2 Data for ARC Applications

The pulled tube leak test, burst test and destructive examination results are summarized in Table 3-6. The R8C60, TSP 1 indication did not leak at SLB conditions. No leakage for the other indications is inferred from the shallow corrosion depths. Since the TSP 1 indication of R4C23 is field bobbin NDD, this indication cannot be used in the EPRI ARC database for the voltage correlations.

The Sequoyah Unit-2 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. Criteria 1c to 1e are not applicable to the Sequoyah Unit-2 indications. The indication at R4C23, TSP 2 requires evaluation against criteria 1a and 1b. Criterion 1a applies to indications with corrupted bobbin voltage measurements which includes extraneous (not ODSCC) factors influencing the voltage measurements. Criterion 1b applies to an inappropriate burst test. The 0.35 volt TSP 2 response for R4C23 is apparently a false signal for the associated 2% depth since the 2% depth would not be detectable by bobbin inspection. The bobbin voltage would be associated with deposits, TSP effects or other contribution to a mixed residual signal and exclusion Criterion 1a is applicable to this indication. This is consistent with the indication not being detectable by any other probe (+ Point, UT, etc.). In addition, the indication burst in the free span outside the TSP and is thus not associated with the bobbin voltage measurement. Although the burst test was appropriately performed and burst outside the TSP is reasonably expected for the destructive exam results, data exclusion Criterion 1b is applicable to the burst data since the burst pressure is not associated with the flaw at the TSP. Therefore, the R4C23, TSP 2 indication is excluded from all ARC correlations per Criteria 1a and 1b. Criterion 3 applies to potential errors in the leakage measurements and is not applicable to the Sequoyah Unit-2 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 R8C60, TSP 1 indication has two ligaments with a maximum depth of 60%. However, the indication lies almost on the mean burst correlation and does not satisfy the exclusion criterion. The R8C60, TSP 2 indication has two ligaments with a maximum depth of 50%. However, the indication lies just below the mean burst correlation and does not qualify for exclusion from the database.

As shown in the last column of Table 3-6, the TSPs 1 and 2 indications of R8C60 are to be included in the probability of leakage and burst correlations. The indication at R4C23, TSP 2 is excluded from the database per EPRI exclusion Criteria 1a and 1b. The impact of the indications on the ARC correlations is further discussed in Section 3.4.

3.4 Comparison of Sequoyah Unit-2 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-2 in 1996. The results of the destructive examination of the tube sections is recorded in Section 3.1 of this report. The Sequoyah 2 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.

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1 The database consisted of the EPRI recommended database as documented in the addendum to EPRI report NP-7480-L.

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 Unit-2 specimens is depicted on Figures 3-13 and 3-14 relative to the burst pressure correlation developed using the latest recommended reference database.[2]

1. A visual examination of the data relative to the EPRI database indicated that the burst pressures measured fall well within the scatter band of the reference data. This evident from the positions of the data within the tolerance band of Figure 3-13 and 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 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 Unit-2 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 decreased by 0.09%.

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

This has the effect of decreasing, albeit not significantly, the predicted burst pressure as a function of the bobbin amplitude.

2. The slope of the regression line is decreased by 0.05%, i.e., the slope is less steep. This has the effect of increasing 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 0.8%. 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 0.1 volt, i.e., from 8.7 volts to 8.8 volts. The decrease in the slope and 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 3-14 illustrates the Sequoyah Unit-2 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 Unit-2 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 0.2% reduction (larger negative value) in the *logistic* intercept parameter.

2. A 0.2% increase in the *logistic* slope parameter.

3. The absolute values of the parameters' covariance matrix changed by 0.3% to 0.4%.

4. The Pearson standard error decreased by 0.1% from 0.571 to 0.566. This is a negarive 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 3-14. An examination of Figure 3-14 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 1.4% for the slope parameter, the use of the correlation in performing Monte Carlo simulations to estimate the total leak rate is 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 Unit-2 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 Unit-2 test data.

Table 3-1
Comparison of NDE Indications Observed at Sequoyah Unit-2 on Pulled S/G Tubes

Location	Field E/C	Lab E/C	Lab UT Data	Lab X-Ray
R4C23, TSP 1, SG 2, CL	Bobbin: NDD (0.29 V DI - non-quantifiable)* RPC: NDD + Point: NDD	Bobbin: 0.64 V DI - non-quantifiable RPC: NDD Cecco: NDD + Point: NDD	NDD	NDD
R4C23, TSP 2, SG 2, CL	Bobbin: 0.41 V, 27% deep, OD PI (0.35 V, 27% deep, OD DI due to tube noise)* RPC: NDD + Point: NDD	Bobbin: 0.45 V, 35% deep, DI RPC: NDD Cecco: NDD + Point: NDD	NDD	Low level wall loss locally (pitting like indications)

()* = Eddy current reevaluation value using cross calibration of ASME standard to reference lab standard.

Legend of Abbreviations:

Ind = Indication
RPC = Rotating Pancake Coil
MCI = multiple circ. ind.
TSP = tube support plate
V = volts
SAI = single axial ind.
MAI = multiple axial ind.
DI = distorted indication
NDD = no detectable degradation
TTS = top of tubesheet
PI = possible indication

Table 3-1 (Continued)
Comparison of NDE Indications Observed at Sequoyah Unit-2
on Pulled S/G Tubes

Location	Field E/C	Lab E/C	Lab UT Data	Lab X-Ray
R8C60, TSP 1, SG 3, HL	Bobbin: 1.1 V, PI (1.1 V, PI - 94% deep)* RPC: SAI, 0.96 V, 0.34" long, 48° of circumferential extent (SAI, 0.60 V, 58% deep, 0.39" long, 45° of circ. extent)* + Point: SAI, 0.31 V, 0.28" long, 50° of circumferential extent (SAI, 0.20 V, 79% deep, 0.28" long, 50° of circ. extent)*	Bobbin: 1.93 V, 21% deep, DI RPC: MAI, 1.78 V, 38% deep, 0.55" long at 235° with a circumferential extent of 135° Cecco: PI with a circumferential extent of 120°, 68% max. depth + Point: MAI, (distorted), 0.22 V, 75% deep, 0.53" long at 224° with a circumferential extent of 129°	Network of indications in axial and circumferential directions on the OD located between 188 and 317° with a depth of 20 to 30%. Also shallow indications (less than 20% deep) located between 9 and 21° and at 38°.	NDD.
R8C60, TSP 2, SG 3, HL	Bobbin: NDD RPC: NDD + Point: NDD	Bobbin: 4.24 V dent in TSP 2 and 0.79 V dent at 2.60" below TSP 2 RPC: Lift off signals, possible SAI, 0.23 V, 0.30 long, 41° of circumferential extent, non-quantifiable depth Cecco: PI with a circumferential extent of 45°, dent with distorted indication (estimated depth < 20%) + Point: SAI, (distorted) , 0.19 V, < 20% deep, 0.36" long at 303° with 56° of circumferential extent	Network of shallow indications (less than 20% deep) in axial and circumferential directions on the OD located between 110 and 171° and 236 and 300°.	Low level wall loss locally (pitting like indications)

Table 3-2
Room Temperature Burst and Tensile Test Data for Sequoyah Unit-2 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, %
R4C23, FS, SG 2, CL	12422	32.6	2.008	0.383	56,779	107,416	37.1
R4C23, TSP 1, SG 2, CL	12378	31.8	1.988	0.375			
R4C23, TSP 2, SG 2, CL	12305	32.2	1.933	0.383			
R8C60, FS, SG 3, HL	11616	24.2	2.285	0.310	55,730	107,865	38.3
R8C60, TSP 1, SG 3, HL	9434	14.1	1.264	0.331			
R8C60, TSP 2, SG 3, HL	10269	15.3	1.382	0.310			
Control, NX8161	11587				52,308	102,615	35.7

Legend:

TSP = tube support plate; FS = free span, TTS = top of tubesheet; SG = 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-2 SG Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R8C69, TSP 1, SG 3, HL (Axial Burst Crack)	0.00/00 0.02/05 0.04/03 0.06/05 0.08/08 0.10/25 0.12/10 0.14/08 0.16/20 0.18/53 0.20/45 0.22/50 0.24/50 0.26/50 <---Ligament 1/ 0.008" wide 0.28/50 0.30/50 0.32/50 0.34/58 (0.36/60)<---(Max. depth = 60%) 0.38/50 0.40/51 <---Ligament 2/ 0.005' wide 0.42/45 0.44/43 0.46/40 0.48/55 0.50/40 0.52/08 0.523/00 Ave. depth = 34% Macrocrack Length = 0.523 inch	Crack Top (located 0.10" below TSP top) Crack Bottom (located 0.623" below TSP top)	The axially oriented burst macrocrack had two ductile ligaments with dimple rupture features occurring over more than 50% of their lengths.

Table 3-3 (Continued)
Sequoyah Unit-2 SG Tube Intergranular Macrocrack Profiles for OD Origin Corrosion

Tube, Specimen	Length vs. Depth & Ductile Ligament Data (inches/% throughwall)	Positional Information	Comments
R8C60, TSP 2, SG 3, HL (Axial Burst Crack)	0.00/00 0.02/06 0.04/16 0.06/16 0.08/12 0.10/06 0.12/25 0.14/22 0.16/35 0.18/31 0.20/31 0.22/28 <---Ligament 1/ 0.010" wide 0.24/25 0.26/38 0.28/31 0.30/25 0.32/38 0.34/41 <---Ligament 2/ 0.006 wide 0.36/35 0.38/35 (0.40/50) <--(Max. depth = 50%) 0.42/28 0.44/28 0.46/19 0.48/12 0.50/06 0.52/05 0.54/06 0.56/06 0.58/03 0.602/00 Ave. depth = 21%, Macrocrack Length = 0.602 inch	Crack Top (located 0.125" below TSP top) Crack Bottom (located 0.727" below TSP top)	The axially oriented burst macrocrack had two ductile ligaments with dimple rupture features occurring over more than 50% of their lengths.

Table 3-4
Metallographic Data of Sequoyah Unit-2 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 Oblique and Axial Components (% Throughwall in Radial Section)	Avg. D/W Ratio from Transverse Section
R4C23, TSP 1, SG 2, CL	Transverse - Burst Opening (1.1" above TSP top)	0	2.75	0	0	NA	NA	NA
	Transverse - (Mid TSP)	0	2.75	0	0	NA	NA	NA
R4C23, TSP 2, SG 2, CL	Transverse - Burst Opening (0.5" above TSP top)	0	2.75	0	0	NA	NA	NA
	Transverse - (Mid TSP)	0	2.75	0	0	NA	NA	NA
R8C60, TSP 1, SG 3,HL	Transverse - (Mid TSP)	23	2.02	11	45	51/21		10
	Radial	18	0.36	50		depth = 2%	24%<Oblique<50% Axial>50%	
	Radial	14	0.39	36		depth = 10%		
	Radial	15	0.41	36		depth = 24%		
	Radial	4	0.41	11		depth = 50%		
R8C60, TSP 2, SG 3,HL	Transverse - (Mid TSP)	17	2.06	8	40	20/8		6
	Radial	18	0.38	47		depth = 2%	2%<Oblique<10% Axial>34%	
	Radial	12	0.39	31		depth =10%		
	Radial	11	0.41	27		depth = 24%		
	Radial	2	0.41	5		depth = 34%		

* Minor isolated surface corrosion, ≤ 2% deep, was noticed in some areas on the tube OD.

Table 3-5. Summary of Plant W-2 1996 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[2]	Depth	+ Pt. Volts	Bobbin Volts	RPC 3-Coil	+ Point	Cecco	UT
R8C60 Hot Leg	1	1.10	0.31 v SAI	1.01	1.081	1.09(1.10)	85%	0.24 v MAI	1.93	1.78 v MAI	0.22 v MAI	PI	MAI
	2	NDD	NDD	0.19	1.081	0.20(NDD)	DI	0.18 v SAI	Dented	0.23 v	0.19 v	PI	MAI
R4C23 Cold Leg	1	NDD	NDD	NDD	-	NDD(0.29)	-	NDD	0.64	NDD	NDD	NDD	NDD
	2	0.41	NDD	0.42	0.842	0.35(0.35)	DI	NDD	0.45 v	NDD	NDD	NDD	NDD

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 standard and is applied to the laboratory reevaluation to obtain the corrected APC volts. Two laboratory reanalyses of the field data are given in the Table. The first value given (without parentheses) is used for ARC evaluations - See text for discussion of the differences.

Table 3-6. Plant W-2 1996 Pulled Tube Data for ARC Applications

Tube	TSP [1]	Bobbin Data		RPC Volts	Destructive Examination 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.	
R8C60 Hot Leg	1	1.09	85%	0.24	60%	34%	0.523"	2	0.0	0.0	9.434			7.932	B, POL
	2	0.20	DI	0.18	50%[6]	21%	0.602"	2	0.0[3]	0.0[3]	10.269			8.634	B, POL
	FS										11.616	55.7	107.9	9.767	
R4C23 Cold Leg	1	NDD	-	NDD	0%	-	-	-	0.0[3]	0.0[3]	12.378 Outside TSP			10.370	None
	2	0.35	DI	NDD	2%	-	-	-	0.0[3]	0.0[3]	12.305 Outside TSP			10.309	None
	FS										12.422	56.8	107.4	10.407	

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 68.78 ksi, average flow stress at 650° F for 7/8" diameter tubes (Reference 3.6).
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.
6. Crack is > 30% deep only over about 0.1".

Table 3.7: Effects of the Sequoyah Unit 2 Data on the Burst Pressure vs. Bobbin Volts Correlation [1]

$$P_B = \alpha_1 + \alpha_2 \log(Volts)$$

Parameter	Reference Database Value [2]	Database with Sequoyah-2
α_1	7.6003	7.5938
α_2	-2.3645	-2.3528
σ_{Error}	0.8285	0.8222
N (data pairs)	79	81
p Value for α_2	$2.5 \cdot 10^{-30}$	$3.4 \cdot 10^{-31}$
r^2	81.9%	82.0%

Notes: (1) The reference flow stress for the determination of the parameters of the correlation equation was 68.78 ksi.

(2) The reference database is as documented in the addendum to EPRI NP-7480-L.

Table 3.8: Effect of Sequoyah Unit 2 Data on the Probability of Leak Correlation

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

Parameter	Reference Database Value [(1)]	Database with Sequoyah-2
β_1	-5.5778	-5.5875
β_2	7.4334	7.4446
V_{11} [(2)]	2.0432	2.0353
V_{12}	-2.3713	-2.3623
V_{22}	3.2038	3.1941
DoF [(3)]	94	98
Deviance	24.61	24.62
Pearson σ_{Error}	0.571	0.566

Notes:
(1) The reference database is as documented in the addendum to EPRI NP-7480-L.
(2) Parameters V_{ij} are elements of the covariance matrix of the coefficients, β_k, of the above regression equation.
(3) Degrees of Freedom

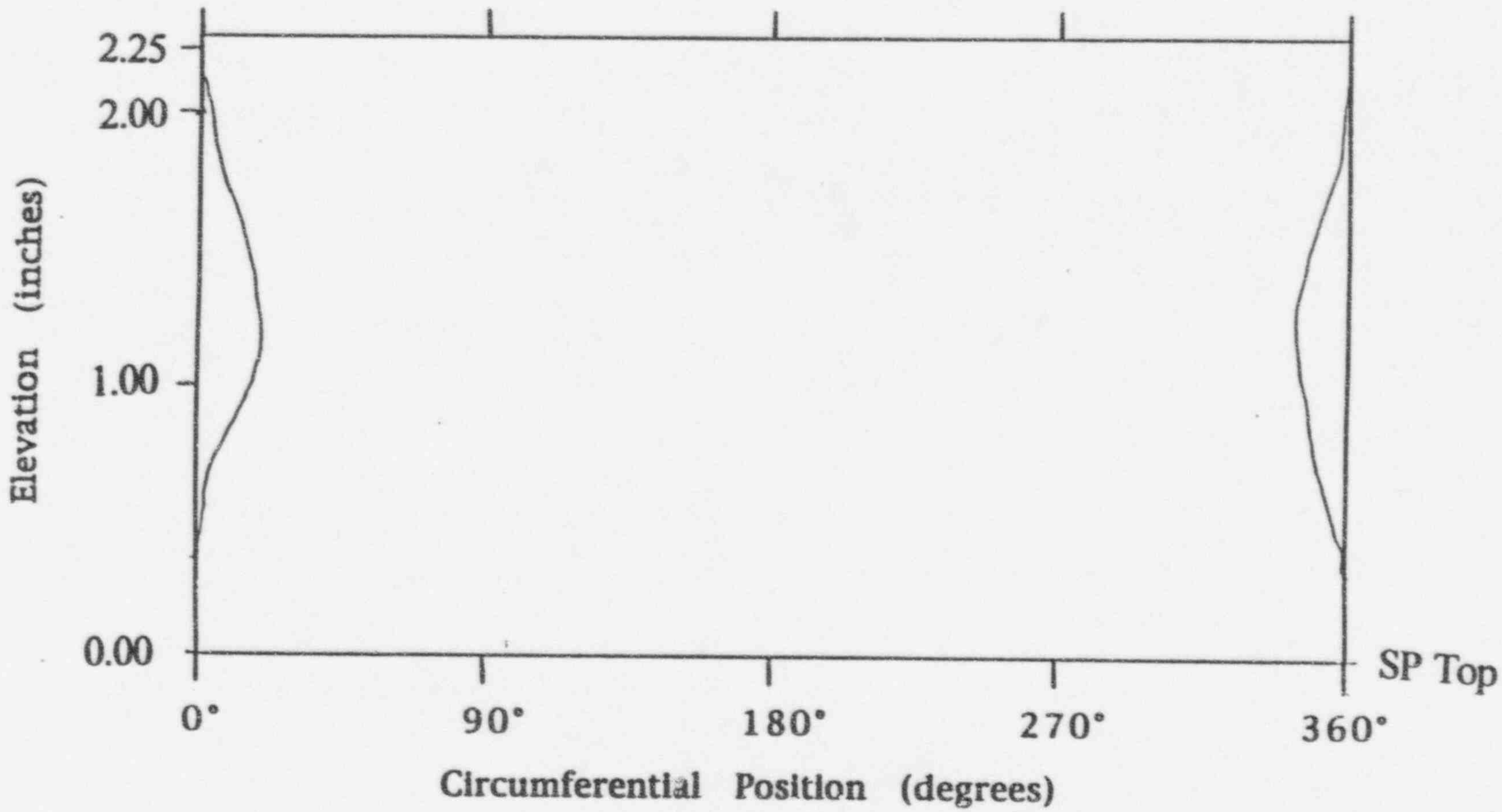


Figure 3-1 Sketch of the OD surface showing the burst fracture opening at the top of the first tube support plate (TSP1) of Tube R4C23. No cracking was noticed on the fracture face and OD surface of the tube.

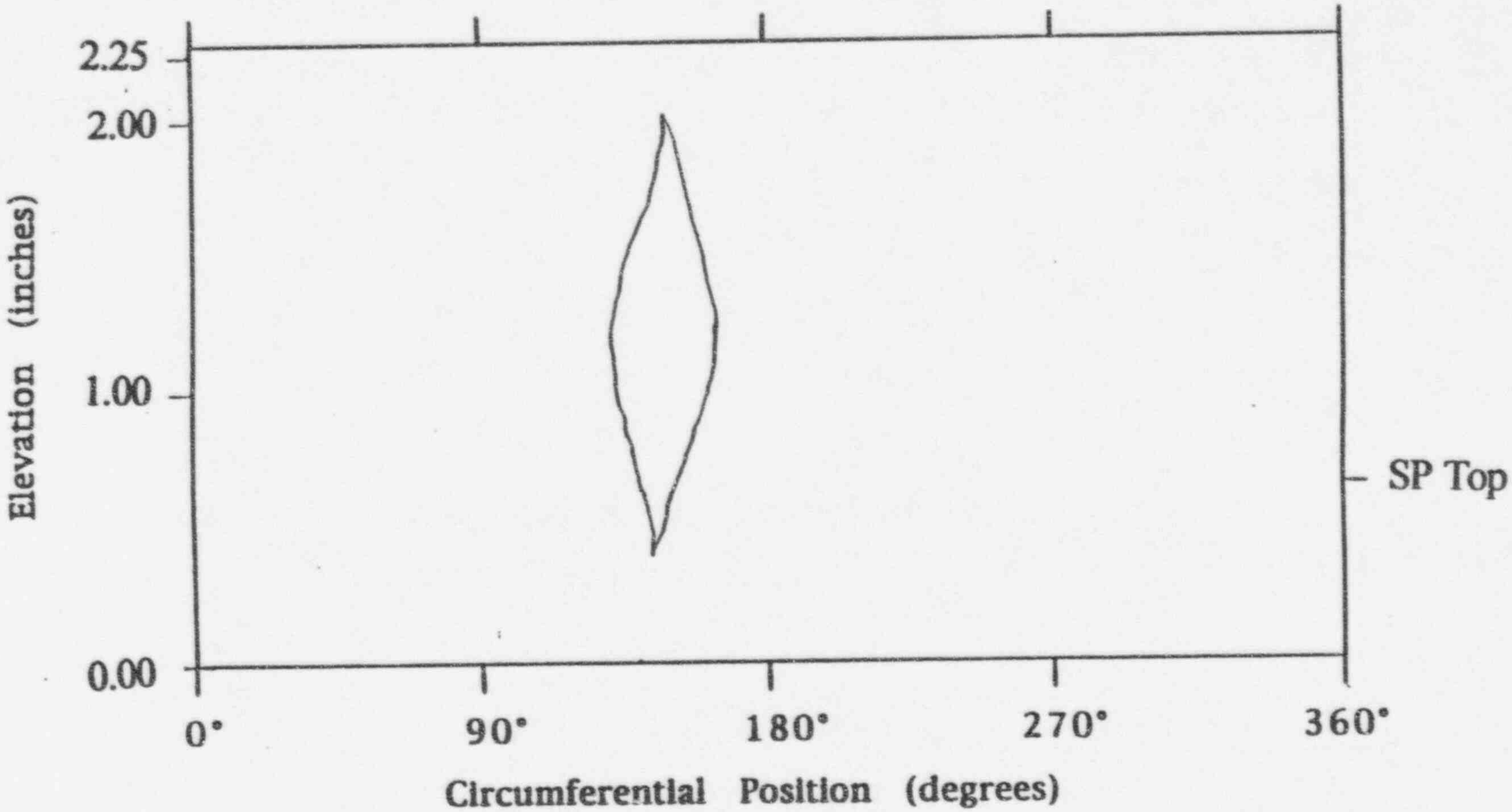


Figure 3-2 Sketch of the OD surface showing the burst fracture opening at the second tube support plate (TSP2) of Tube R4C23. The burst opening extended above the top of TSP crevice region. No cracking was noticed on the fracture face and OD surface of the tube.

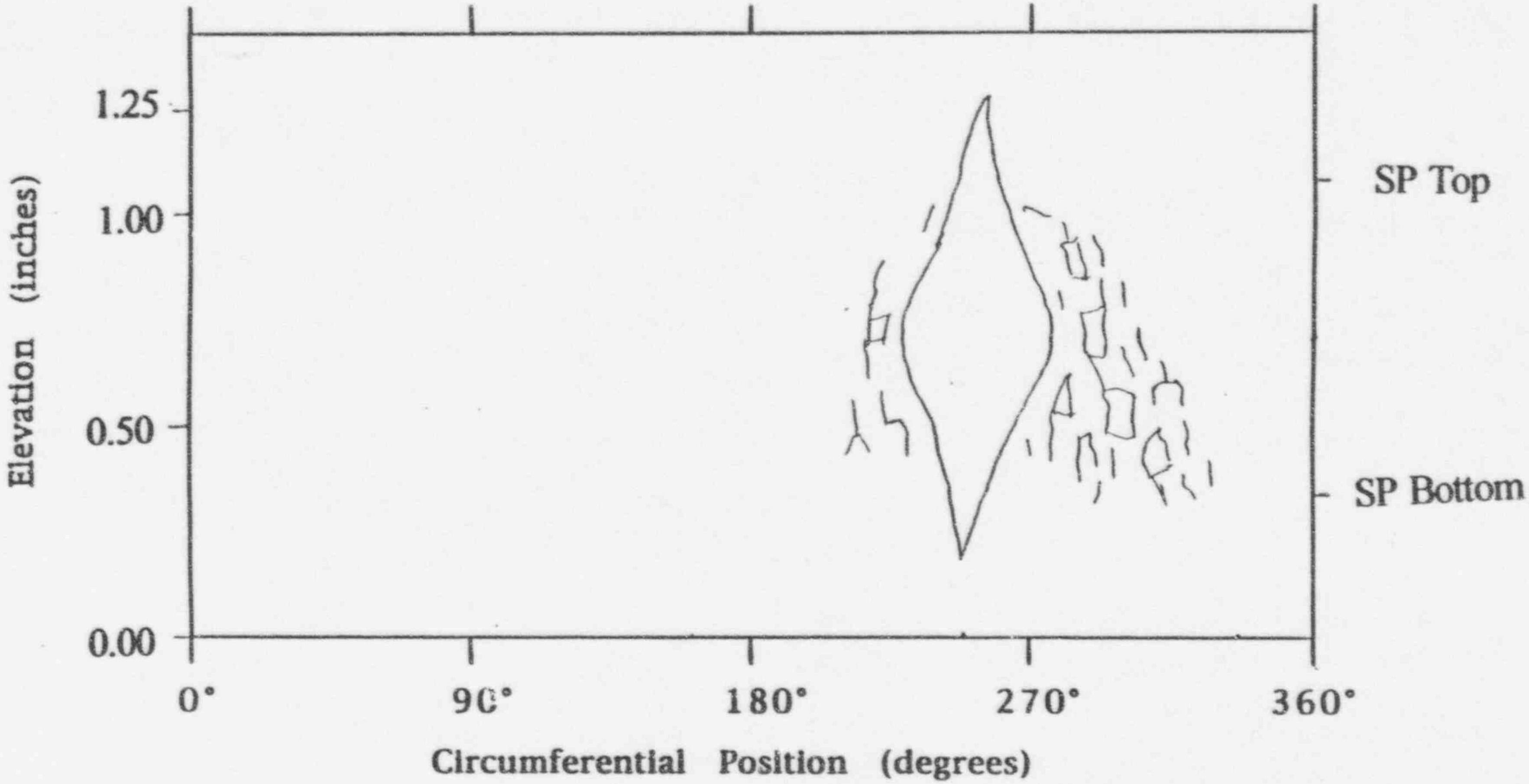


Figure 3-3 Sketch of the OD crack distribution found at the first support plate (TSP1) of Tube R8C60. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

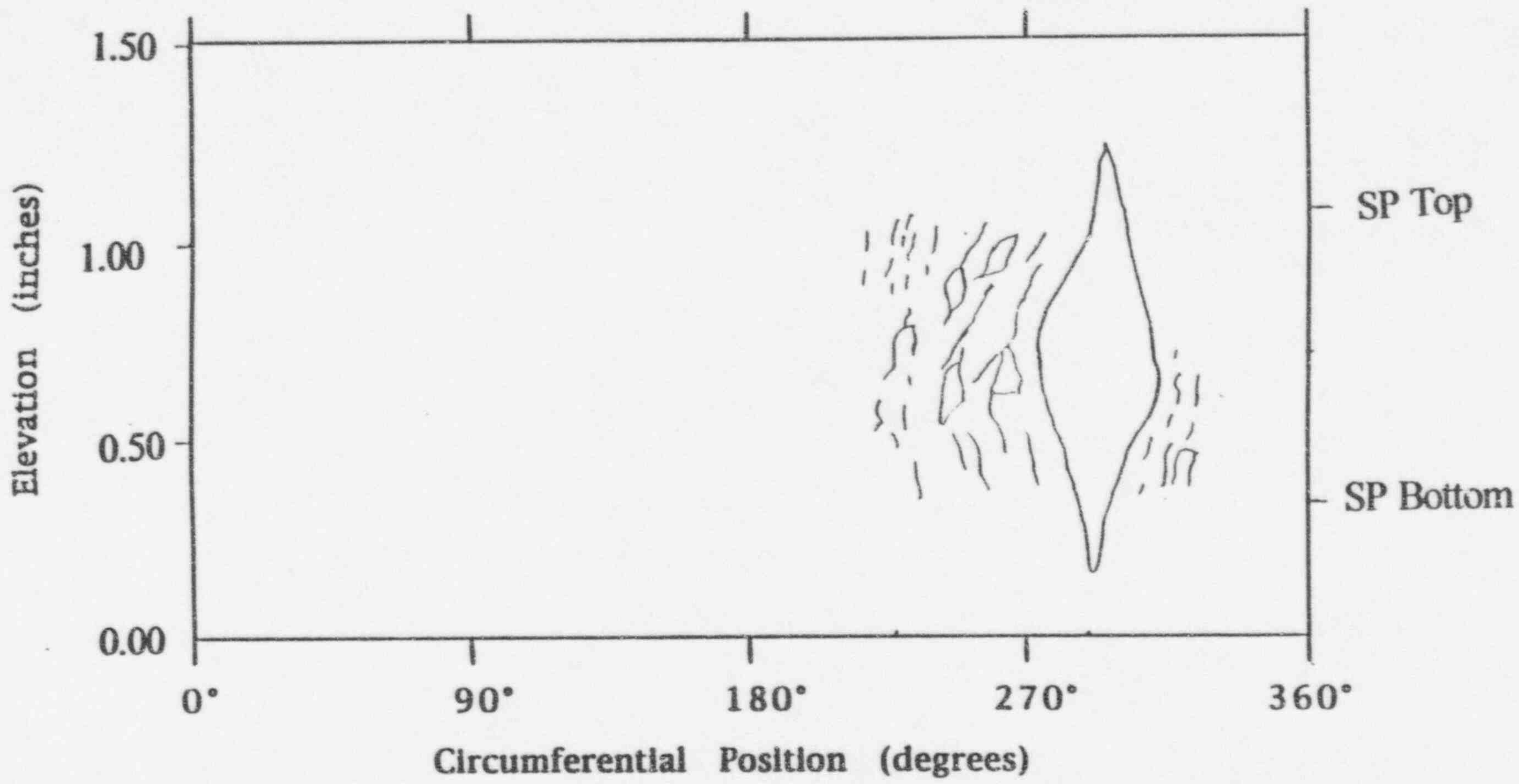


Figure 3-4 Sketch of the OD crack distribution found at the first support plate (TSP2) of Tube R8C60. Also shown is the location of the burst fracture opening. The burst opening extended beyond the TSP crevice region, but the corrosion cracking was confined to the crevice region.

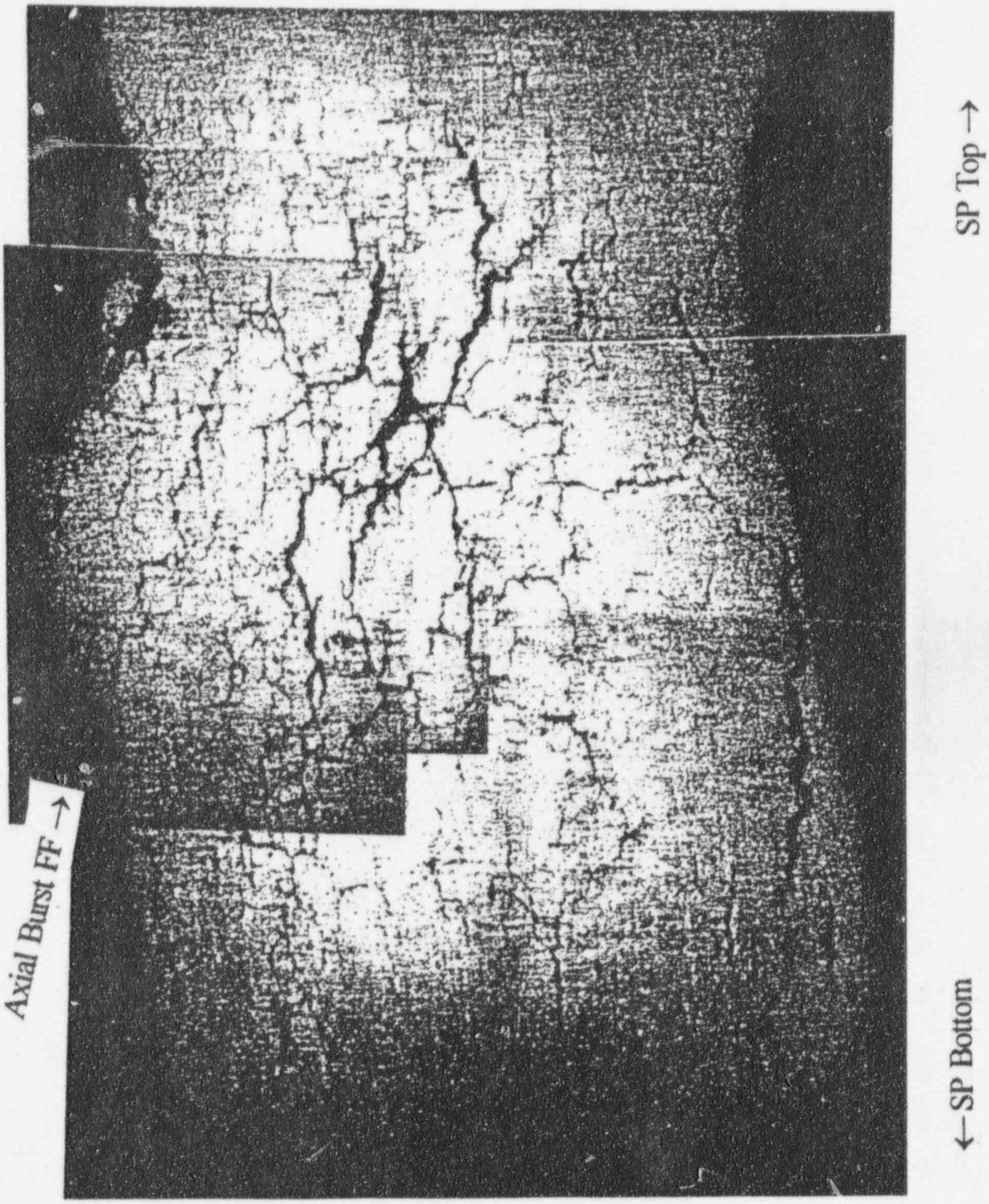


Figure 3-5 OD radial metallography showing intergranular cellular corrosion (ICC) present along with the more dominant axial intergranular stress corrosion cracking (IGSCC) at the first tube support plate (TSP1) of Tube R8C60. 16X Mag. 2% depth.

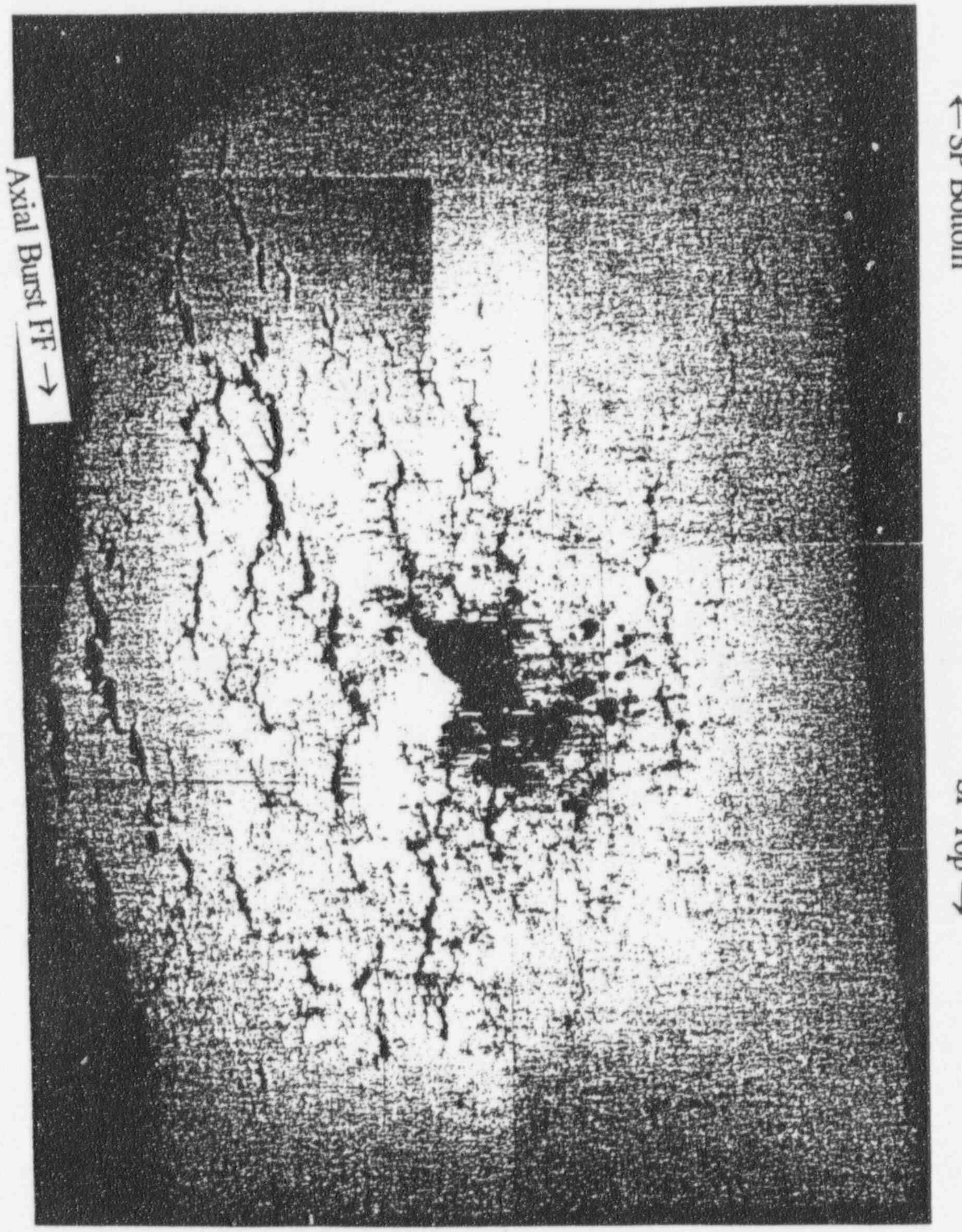
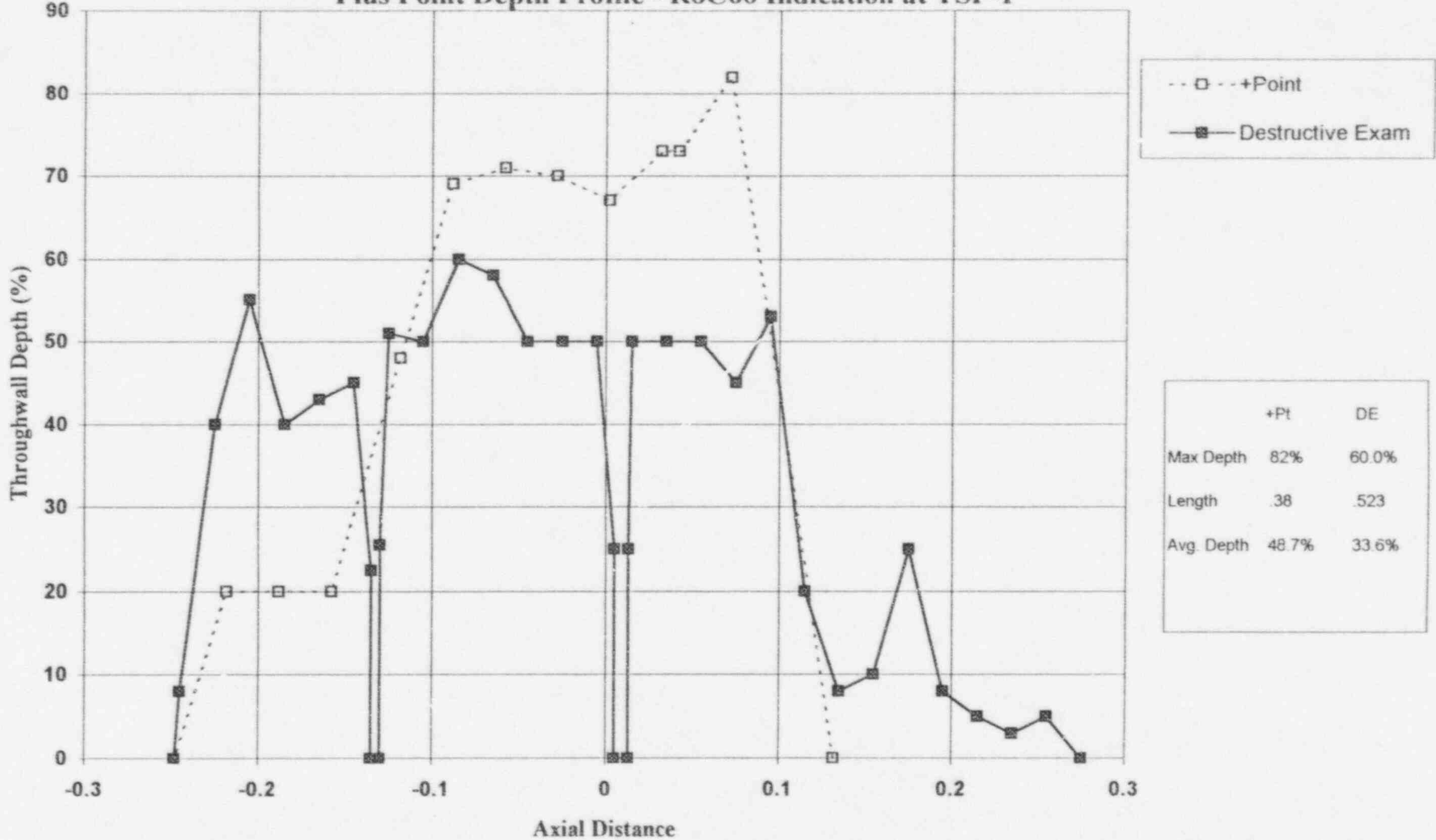


Figure 3-6 OD radial metallography showing intergranular cellular corrosion (ICC) present along with the more dominant axial intergranular stress corrosion cracking (IGSCC) at the second tube support plate (TSP2) of Tube R8C60. 16X Mag. 2% depth.

Figure 3-7
Sequoyah Unit 2 1996 Pulled Tube
Plus Point Depth Profile - R8C60 Indication at TSP-1



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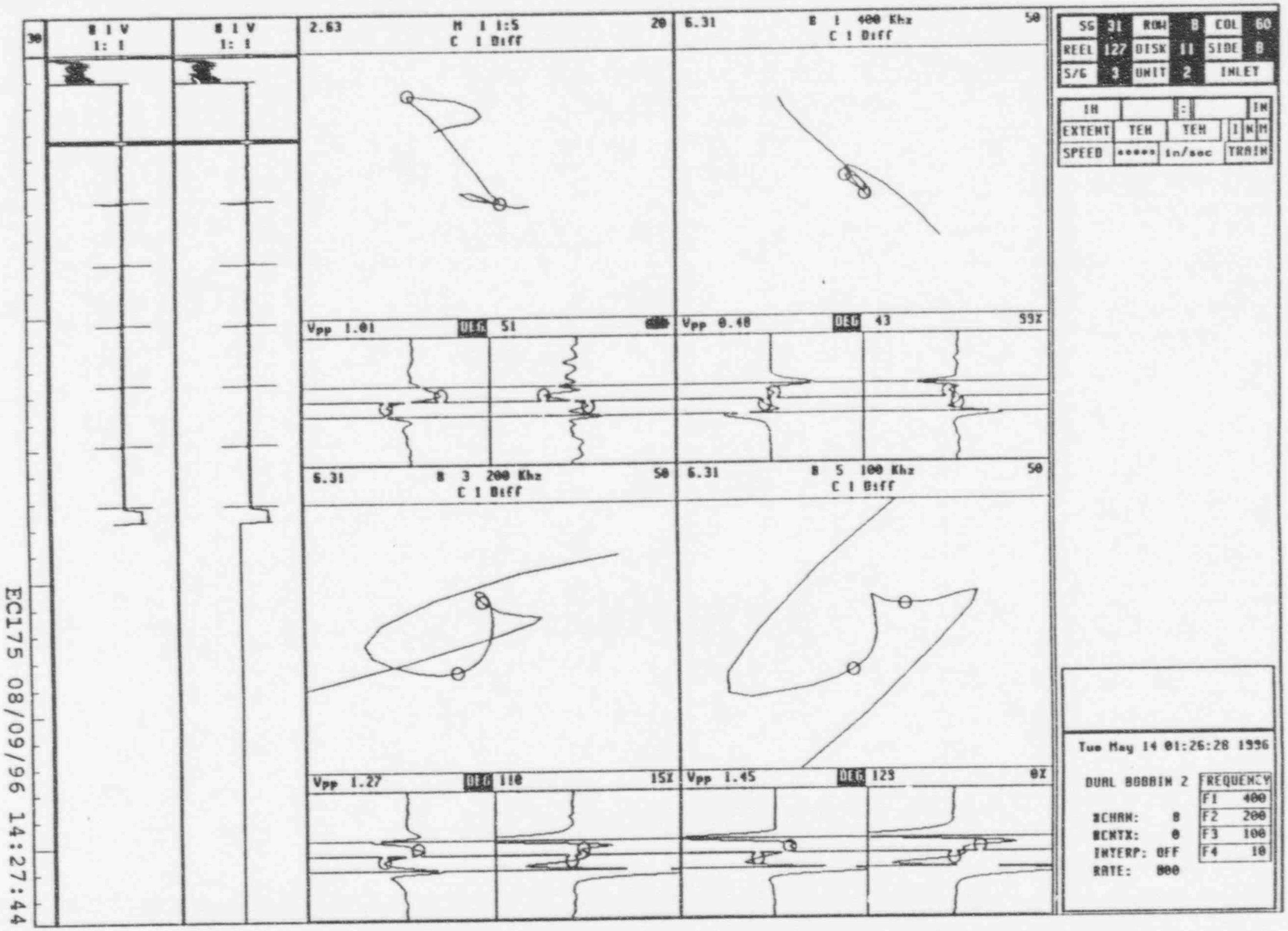

Figure 3-8 SG 3 R8C60 TSP 1: Results of Laboratory Reanalysis of Field Bobbin data

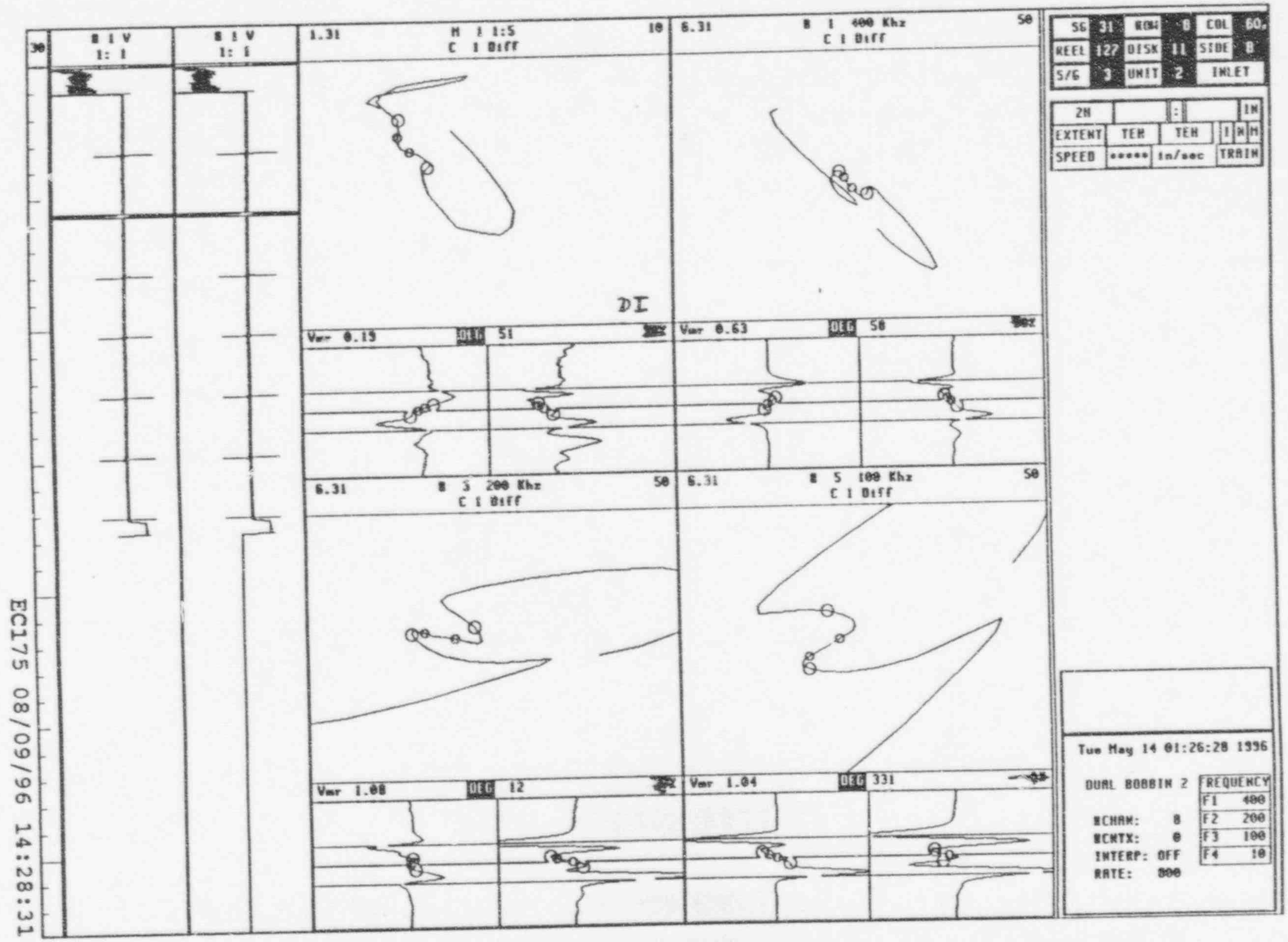

Figure 3-9 SG 3 R8C60 TSP 2: Results of Laboratory Reanalysis of Field Bobbin data

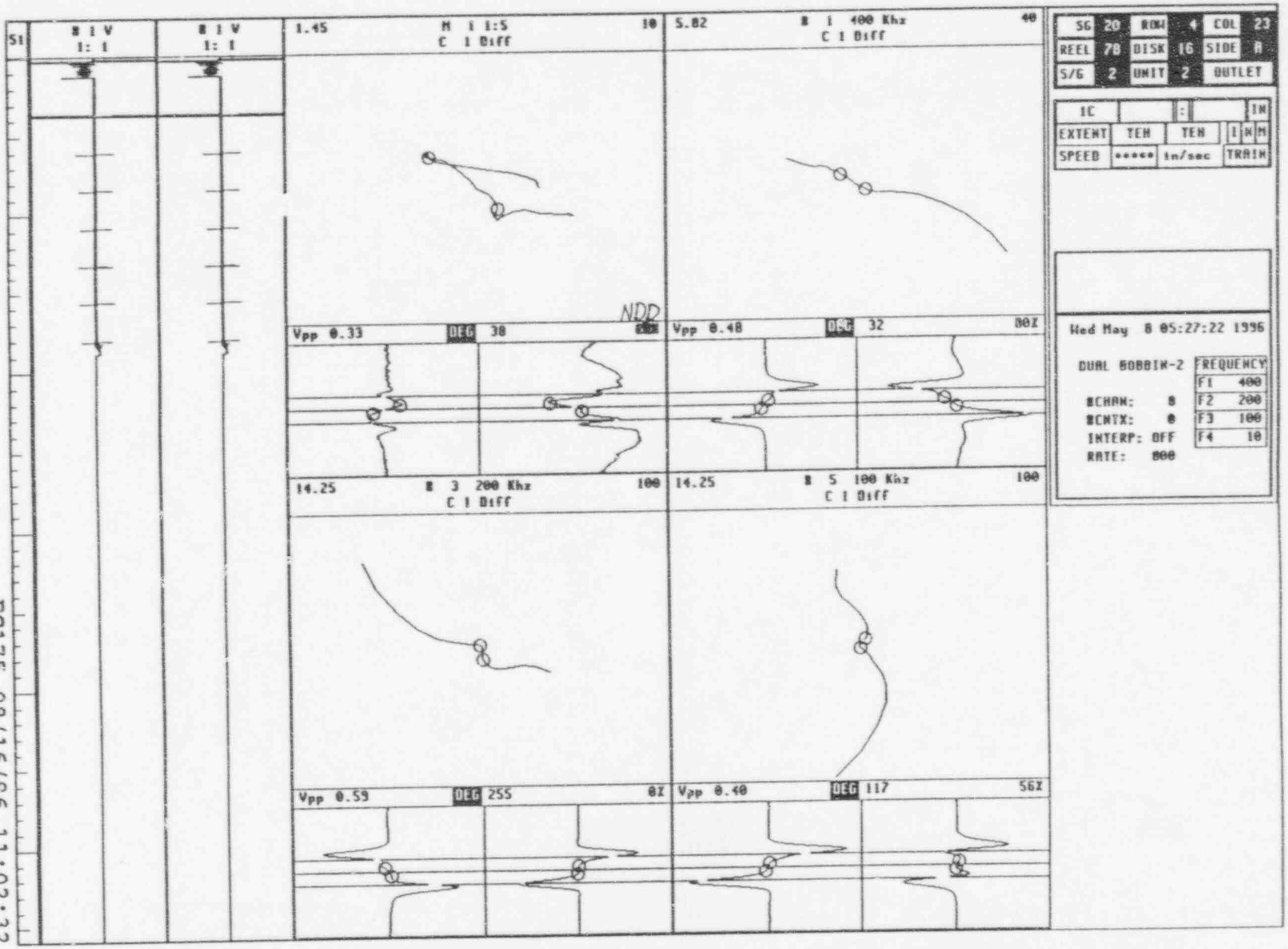

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Figure 3-10 SG 2 R4C23 TSP 1: Results of Laboratory Reanalysis of Field Bobbin data

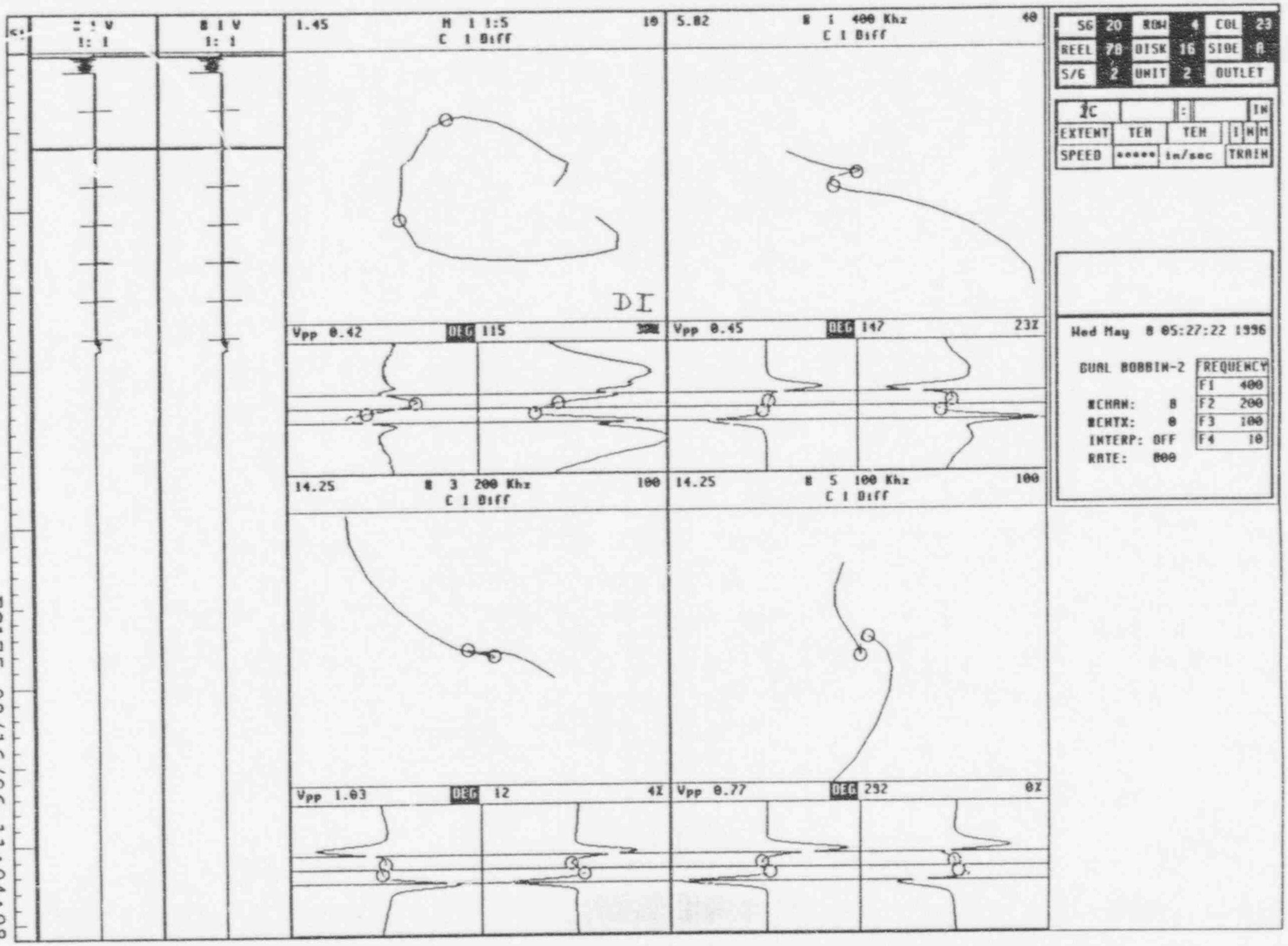

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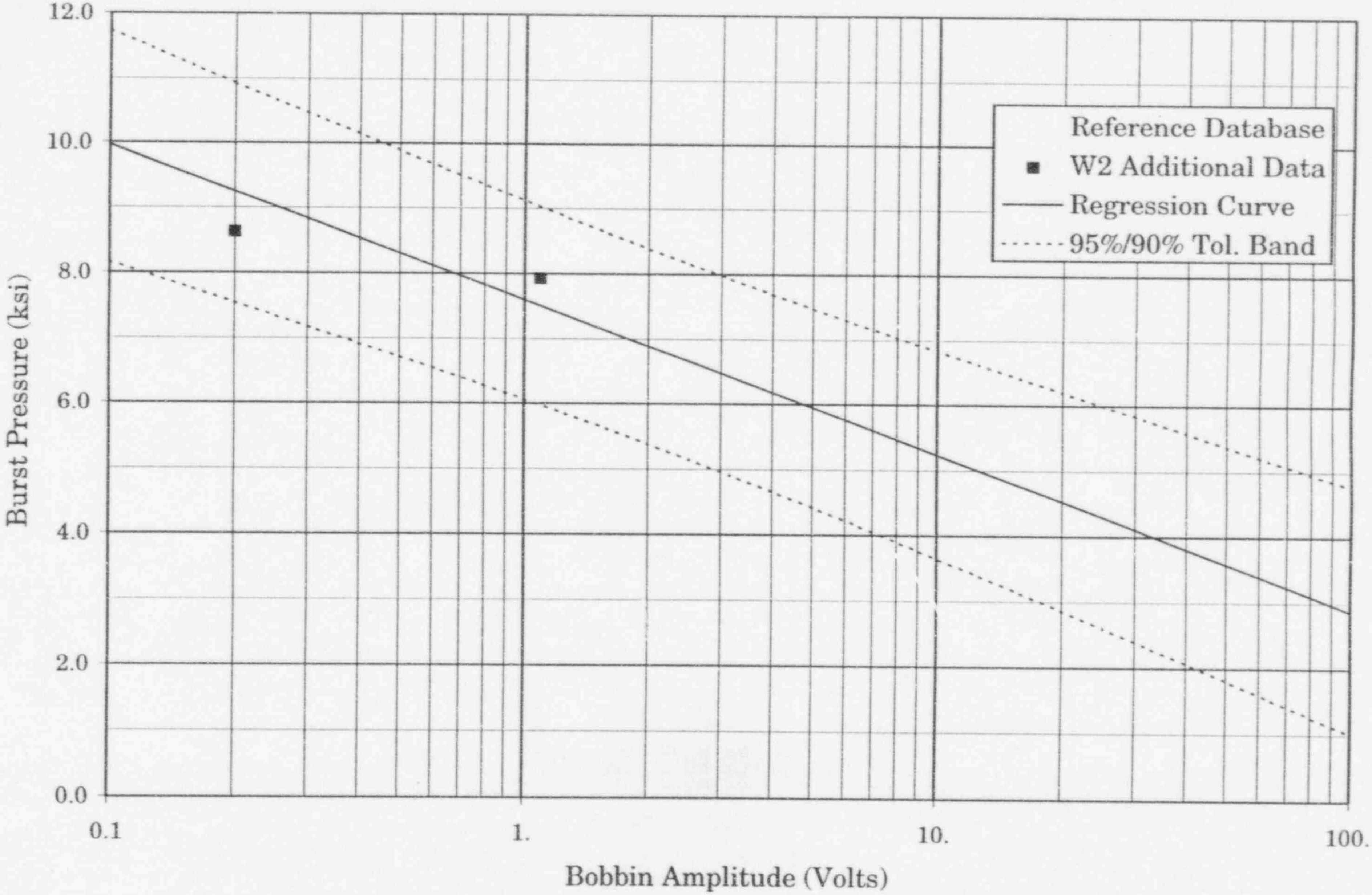
Figure 3-11 SG 2 R4C20 TSP 2: Results of Laboratory Reanalysis of Field Bobbin data

Figure 3-12: Burst Pressure vs Volts for 7/8" Alloy 600 SG Tubes

Additional Data, Reference σ_f = 68.78 ksi @ 650°F



[78BV_896.xls] Tol.Band

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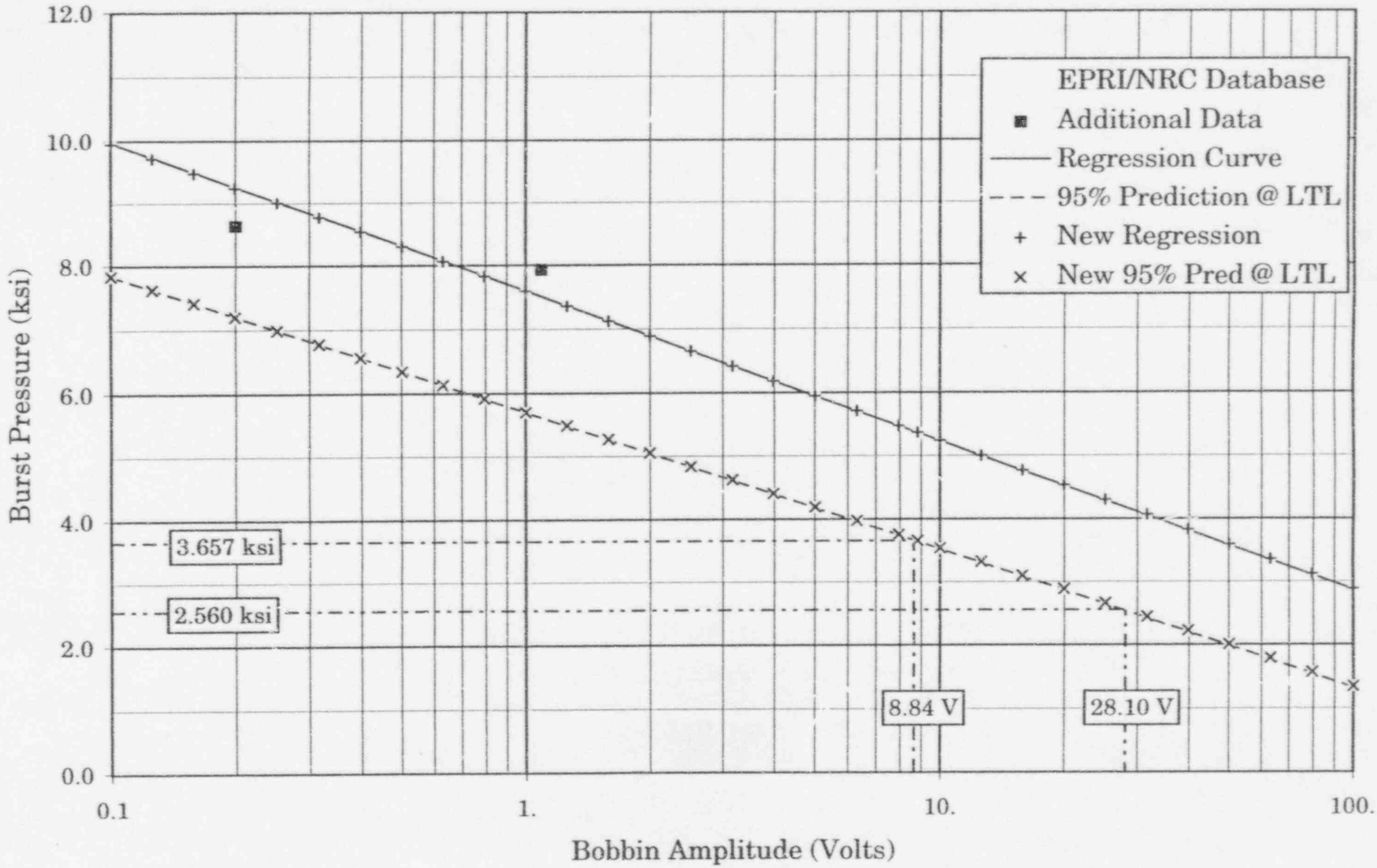
Figure 3-13: Burst Pressure vs Volts for 7/8" OD Alloy 600 SG Tubes

Reference Database, Reference σ_f = 68.78 ksi @ 650°F



[78BV_896.xls] BvsV.NRC

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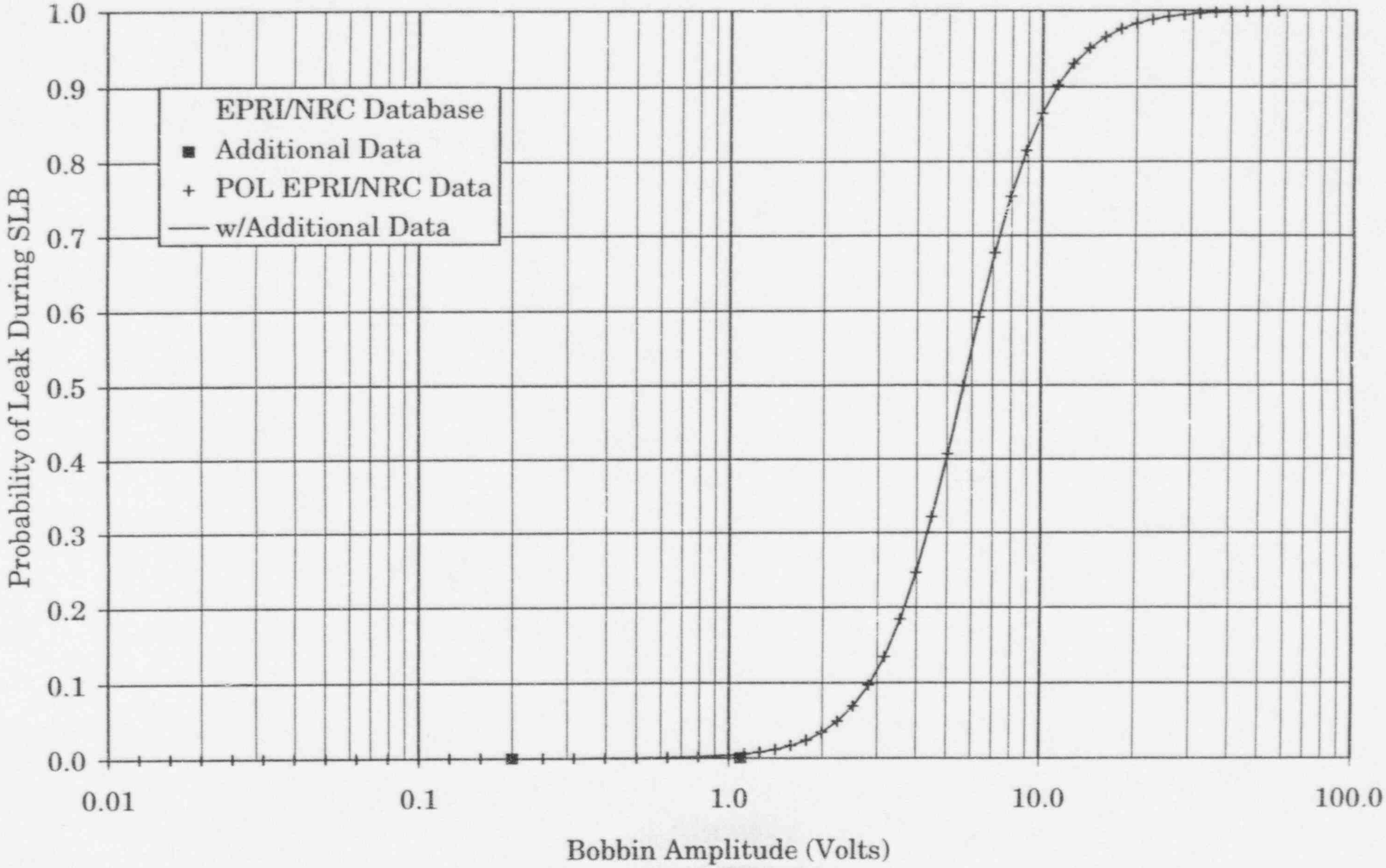
Figure 3-14: Probability of Leak for 7/8" SG Tubes

Effect of Inclusion of Additional 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-2 SGs consisted of a complete, 100% Eddy Current Test (ECT) bobbin probe full length examination of all hot leg and cold leg tube support plate (TSP) intersections in the tube bundles of the four SGs. A 0.720 inch diameter probe was used for all hot leg and cold leg TSP indications where APC was applied. A total of 366 axial TSP ODSCC indications were found in all four steam generators in the current inspection, of which only four indications had a voltage above one volt and none above two volts. Therefore, no tube repairs were made because of ECT voltages exceeding the 2 volt repair limits. An augmented RPC inspection was performed consistent with the Generic Letter 95-05 requirements. The augmented RPC inspection using the +Point probe included examination of all TSP intersections in all four SGs with a dent voltage over 5.0 volts. In addition, a total of 79 mixed residual signals with a bobbin voltage above about 2 volts were also inspected with a pancake coil; none had a flaw-like signal. There were no RPC circumferential indications at the TSPs, no RPC indications with potential PWSCC phase angles, and no indications extending beyond the TSP edges. No flaw indications were found in any dents above 5 volts. All RPC responses were consistent with that expected for ODSCC at TSP intersections.

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 Unit-2 show the following.

- A total of 366 indications were detected at the TSP intersections during the EOC-7 inspection, and they all had a bobbin voltage below 2 volts.
- Of the 366 indications detected during the EOC-7 inspection, a total of 12 were RPC inspected.
- Only two indications were RPC confirmed (both below 2 volts).
- Two indications were removed from service due to tube being pulled to confirm ODSCC, and the remaining 364 indications were returned to service for Cycle 8.

A review of Table 4-1 indicates that SG 4 had the largest number of indications at EOC-7 (a quantity of 170, all below 1.0 volt), thereby it potentially could be the limiting SG at EOC-8. Two indications above 1 volt were found each in SGs 2 and 3, and the largest bobbin voltage measured is 1.65 volts (in SG 2).

The distribution of EOC-7 indications as a function of support plate location is summarized in Table 4-2 and illustrated in Figure 4-2. 326 out of 366 indications were found at the hot leg intersections, of which 254 indications (about 78%) were at the first two TSP intersections. The remaining 40 indications were detected at the cold leg TSP intersections, of which 24 were at the first two TSPs. Eight cold leg indications were tested with a RPC probe; they were all NDDs. This distribution indicates the predominant temperature dependence of ODSCC at Sequoyah Unit-2 and is consistent with the pattern generally found in other plants, i.e., ODSCCs are found mostly in the first few hot leg TSPs.

4.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at the end of Cycle 8 operation, voltage growth rates were developed from EOC-7 inspection data and a reevaluation of the same indications from the EOC-6 inspection EC signals. Table 4-3 shows the cumulative probability distribution of growth rate per EFPY for each Sequoyah Unit-2 steam generator during Cycle 7. These growth data are also plotted in Figure 4-3. Among the four steam generators, SG 2 has a slightly larger average voltage growth during Cycle 7, and it also has the indication with the largest voltage growth. The curve labelled 'cumulative' in Figure 4-3 represents averaged composite growth data from all four SGs.

Since only a small number of indications were found during the previous inspections, no historical growth data is available for Sequoyah Unit-2. Therefore, in Figure 4-4 the growth rates for Sequoyah Unit-2 are compared with those for Cycle 7 operation of Unit-1 as well as those for another plant with Model 51 SGs that has also implemented APC. Cycle 7 growth rates for Sequoyah Unit-2 are slightly higher than those observed for Unit-1; however, relatively fewer indications were found in the Unit-1 Cycle 7 inspection and the Unit-1 growth rate distribution shown in Figure 4-4 is based on data from only 43 indications Thus, no firm conclusions can be drawn regarding the slight differences noted in the growth rates for the two units.

The average growth rate for Cycle 7 of Unit-2 is about 2/3rds of that found for Plant A during the cycle in which APC was applied for the first time (the cycle in which significant number of indications appeared at the TSPs). The design-basis hot leg temperatures for Sequoyah Unit-2 and Plant-A are within about 1°C and, thus, it is meaningful to compare the growth rates for the two plants. In general, growth rates for TSP indications decrease significantly a few cycles after APC is applied initially (i.e., a few cycles after a significant number of TSP indications appear the first time). For example, between first time and third time application of APC for Plant A the

average growth rate decreased by about 2/3rds, as evident in Figure 4-4. Thus, growth rates for Unit-2 may also decrease significantly in the next few cycles. The Sequoyah Unit-2 average growth of about 60% (Table 4-4) applies to very small BOC voltages (364 of 366 BOC volts are below 0.75 volt) for which percentage growth is high while changes in voltages are small (0.12 volt average). The maximum growth value of 0.7 volt is smaller than found in most APC applications.

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. As the Sequoyah Unit-2 Cycle 7 composite growth data contain 366 data points established using reevaluated voltages from EOC-6 and EOC-7 inspection data, they meet the above NRC requirement. Thus, Cycle 7 growth can be used in the Monte Carlo analyses to project SLB leak rates and tube burst probabilities at EOC-8. The analysis methodology described in Reference 9.3 requires the use of the more conservative of composite growth rates and SG-specific growth rates in the Monte Carlo analysis for a specific SG. Since growth rates for SG B are higher than the composite growth rates, they were imposed on all four steam generators to provide a conservative basis for predicting EOC-8 performance.

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, presented in Table 4-5 as well as graphically illustrated in Figure 4-5, are included in the Monte Carlo analyses used to predict the EOC-8 voltage distributions.

Table 4-1
Sequoyah Unit 2, May 1996 Outage
Summary of Inspection and Repair for Tubes in Service During Cycle 7

Voltage Bin	Steam Generator 1					Steam Generator 2					Steam Generator 3				
	In-Service During Cycle 7				BOC-8	In-Service During Cycle 7				BOC-8	In-Service During Cycle 7				BOC-8
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.2	4	0	0	0	4	5	1	0	0	5	7	0	0	0	7
0.3	18	0	0	0	18	9	0	0	0	9	19	0	0	0	19
0.4	13	0	0	0	13	12	5	0	0	12	14	0	0	0	14
0.5	5	0	0	0	5	16	2	0	1	15	18	0	0	0	18
0.6	3	0	0	0	3	8	0	0	0	8	18	0	0	0	18
0.7	0	0	0	0	0	5	0	0	0	5	7	0	0	0	7
0.8	1	0	0	0	1	0	0	0	0	0	6	0	0	0	6
0.9	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1.1	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0
1.6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1.7	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Total	45	0	0	0	45	58	8	0	1	57	93	1	1	1	92
> 1V	0	0	0	0	0	2	0	0	0	2	2	1	1	1	1

Voltage Bin	Steam Generator 4					Combined Data from All Four SGs				
	In-Service During Cycle 7				BOC-8	In-Service During Cycle 7				BOC-8
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	Returned to Service
0.2	12	0	0	0	12	28	1	0	0	28
0.3	36	1	0	0	36	82	1	0	0	82
0.4	40	0	0	0	40	79	5	0	0	79
0.5	37	0	0	0	37	76	2	0	1	75
0.6	18	0	0	0	18	47	0	0	0	47
0.7	12	1	0	0	12	24	1	0	0	24
0.8	6	0	0	0	6	13	0	0	0	13
0.9	5	1	1	0	5	8	1	1	0	8
1	4	0	0	0	4	5	0	0	0	5
1.1	0	0	0	0	0	2	1	1	1	1
1.6	0	0	0	0	0	1	0	0	0	1
1.7	0	0	0	0	0	1	0	0	0	1
Total	170	3	1	0	170	366	12	2	2	364
> 1V	0	0	0	0	0	4	1	1	1	3

Table 4-2 (Sheet 1 of 2)
Sequoyah Unit-2 May 1996
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7

Tube Support Plate	Steam Generator 1					Steam Generator 2					Steam Generator 3				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
H01	11	0.72	0.35	0.35	0.12	19	0.83	0.48	0.61	0.18	42	1.53	0.53	0.54	0.22
H02	9	0.54	0.35	0.42	0.08	16	1.65	0.53	0.91	0.24	19	0.73	0.45	0.28	0.12
H03	0	-	-	-	-	3	0.45	0.42	0.09	0.03	2	0.8	0.51	0.45	0.26
H04	3	0.48	0.35	0.25	0.09	5	0.49	0.28	0.1	-0.01	8	0.8	0.41	0.39	0.11
H05	10	0.86	0.42	0.41	0.14	4	0.67	0.35	0.43	0.12	8	0.62	0.44	0.31	0.12
H06	3	0.42	0.38	0.23	0.18	0	-	-	-	-	4	0.44	0.29	0.15	0.04
H07	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
C07	1	0.29	0.29	-0.03	-0.03	1	1.05	1.05	0.38	0.38	1	0.18	0.18	-0.01	-0.01
C06	1	0.13	0.13	-0.09	-0.09	1	0.21	0.21	0.07	0.07	0	-	-	-	-
C05	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-
C04	1	0.3	0.30	0.11	0.11	1	0.39	0.39	0.21	0.21	0	-	-	-	-
C02	2	0.25	0.25	-0.06	-0.10	6	0.44	0.39	0.25	0.11	1	0.25	0.25	0.04	0.04
C01	4	0.29	0.26	0.27	0.23	2	0.31	0.25	0.21	0.08	8	0.34	0.27	0.25	0.11
Total	45					58					93				

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Table 4-2 (Sheet 2 of 2)
Sequoyah Unit-2 May 1996
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 7

Tube Support Plate	Steam Generator 4					Composite of All Four SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
H01	98	0.98	0.46	0.62	0.18	170	1.53	0.47	0.62	0.19
H02	40	0.85	0.42	0.77	0.20	84	1.65	0.44	0.91	0.18
H03	8	0.53	0.36	0.22	0.13	13	0.8	0.39	0.45	0.13
H04	4	0.3	0.23	0.1	0.04	20	0.8	0.33	0.39	0.07
H05	3	0.5	0.35	0.26	0.17	25	0.86	0.40	0.43	0.13
H06	6	0.85	0.41	0.26	0.18	13	0.85	0.37	0.26	0.13
H07	1	0.81	0.81	0.29	0.29	1	0.81	0.81	0.29	0.29
C07	0	-	-	-	-	3	1.05	0.51	0.38	0.11
C06	1	0.24	0.24	-0.04	-0.04	3	0.24	0.19	0.07	-0.02
C05	5	0.55	0.43	0.18	0.09	5	0.55	0.43	0.18	0.09
C04	3	0.33	0.25	0.12	0.08	5	0.39	0.29	0.21	0.11
C02	1	0.21	0.21	0	0.00	10	0.44	0.33	0.25	0.05
C01	0	-	-	-	-	14	0.34	0.26	0.27	0.14
Total	170					366				

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Table 4-3
Sequoyah Unit-2 May 1996
Growth Rate Distribution per EFPY for Cycle 7

Volts	Steam Generator 1		Steam Generator 2		Steam Generator 3		Steam Generator 4		Cumulative	
	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF	No. of Obs	CPDF
-0.1	2	0.044	1	0.017	2	0.022	1	0.006	6	0.016
0	13	0.333	9	0.172	15	0.183	13	0.082	50	0.153
0.1	8	0.511	17	0.466	25	0.452	54	0.400	104	0.437
0.2	14	0.822	22	0.845	31	0.785	68	0.800	135	0.806
0.3	6	0.956	5	0.931	10	0.892	25	0.947	46	0.932
0.4	2	1.000	2	0.966	9	0.989	7	0.988	20	0.986
0.5	0		1	0.983	1	1.000	1	0.994	3	0.995
0.6	0		0	0.983	0		1	1.000	1	0.997
0.7	0		1	1.000	0		0		1	1.000
Total	45		58		93		170		366	

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Table 4-4
Sequoyah Unit-2 May 1996
Average Voltage Growth During Cycle 7

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	366	0.27	0.161	0.122	59.9%	45.4%
V_{BOC} < .75 Volts	364	0.26	0.161	0.122	60.8%	46.2%
≥ .75 Volts	2	1.01	0.155	0.118	15.4%	11.7%
	Steam Generator 1					
Entire Voltage Range	45	0.23	0.112	0.085	47.6%	36.1%
V_{BOC} < .75 Volts	45	0.23	0.112	0.085	47.6%	36.1%
≥ .75 Volts	0	-	-	-	-	-
	Steam Generator 2					
Entire Voltage Range	58	0.29	0.158	0.120	54.2%	41.2%
V_{BOC} < .75 Volts	58	0.29	0.158	0.120	54.2%	41.2%
≥ .75 Volts	0	-	-	-	-	-
	Steam Generator 3					
Entire Voltage Range	93	0.29	0.162	0.123	55.0%	41.8%
V_{BOC} < .75 Volts	92	0.29	0.159	0.120	55.5%	42.1%
≥ .75 Volts	1	1.06	0.470	0.357	44.3%	33.7%
	Steam Generator 4					
Entire Voltage Range	170	0.26	0.174	0.132	68.1%	51.7%
V_{BOC} < .75 Volts	169	0.25	0.176	0.134	70.0%	53.1%
≥ .75 Volts	1	0.95	-0.160	-0.121	-16.8%	-12.8%

\# Based on Cycle 7 duration of 481 EFPD (1.32 EFPY)

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Table 4-5
Probe Wear and Analyst Variability - Tabulated Values

Analyst Variability Std. Dev = 10.3% Mean = 0.0% No Cutoff	
Value	Cumul. Prob.
-40.0%	0.00005
-38.0%	0.00011
-36.0%	0.00024
-34.0%	0.00048
-32.0%	0.00095
-30.0%	0.00179
-28.0%	0.00328
-26.0%	0.00580
-24.0%	0.00990
-22.0%	0.01634
-20.0%	0.02608
-18.0%	0.04027
-16.0%	0.06016
-14.0%	0.08704
-12.0%	0.12200
-10.0%	0.16581
-8.0%	0.21867
-6.0%	0.28011
-4.0%	0.34888
-2.0%	0.42302
0.0%	0.50000
2.0%	0.57698
4.0%	0.65112
6.0%	0.71989
8.0%	0.78133
10.0%	0.83419
12.0%	0.87800
14.0%	0.91296
16.0%	0.93984
18.0%	0.95973
20.0%	0.97392
22.0%	0.98366
24.0%	0.99010
26.0%	0.99420
28.0%	0.99672
30.0%	0.99821
32.0%	0.99905
34.0%	0.99952
36.0%	0.99976
38.0%	0.99989
40.0%	0.99995

Probe Wear Variability Std. Dev = 7.0% Mean = 0.0% Cutoff at +/- 15%	
Value	Cumul. Prob.
< -15.0%	0.00000
-15.0%	0.01606
-14.0%	0.02275
-13.0%	0.03165
-12.0%	0.04324
-11.0%	0.05804
-10.0%	0.07656
-9.0%	0.09927
-8.0%	0.12655
-7.0%	0.15866
-6.0%	0.19568
-5.0%	0.23753
-4.0%	0.28385
-3.0%	0.33412
-2.0%	0.38755
-1.0%	0.44320
0.0%	0.50000
1.0%	0.55680
2.0%	0.61245
3.0%	0.66588
4.0%	0.71615
5.0%	0.76247
6.0%	0.80432
7.0%	0.84134
8.0%	0.87345
9.0%	0.90073
10.0%	0.92344
11.0%	0.94196
12.0%	0.95676
13.0%	0.96835
14.0%	0.97725
15.0%	0.98394
> 15.0%	1.00000

Figure 4-1
Sequoyah Unit 2, May 1996 Outage
Bobbin Voltage Distributions for Tubes in Service During Cycle 7

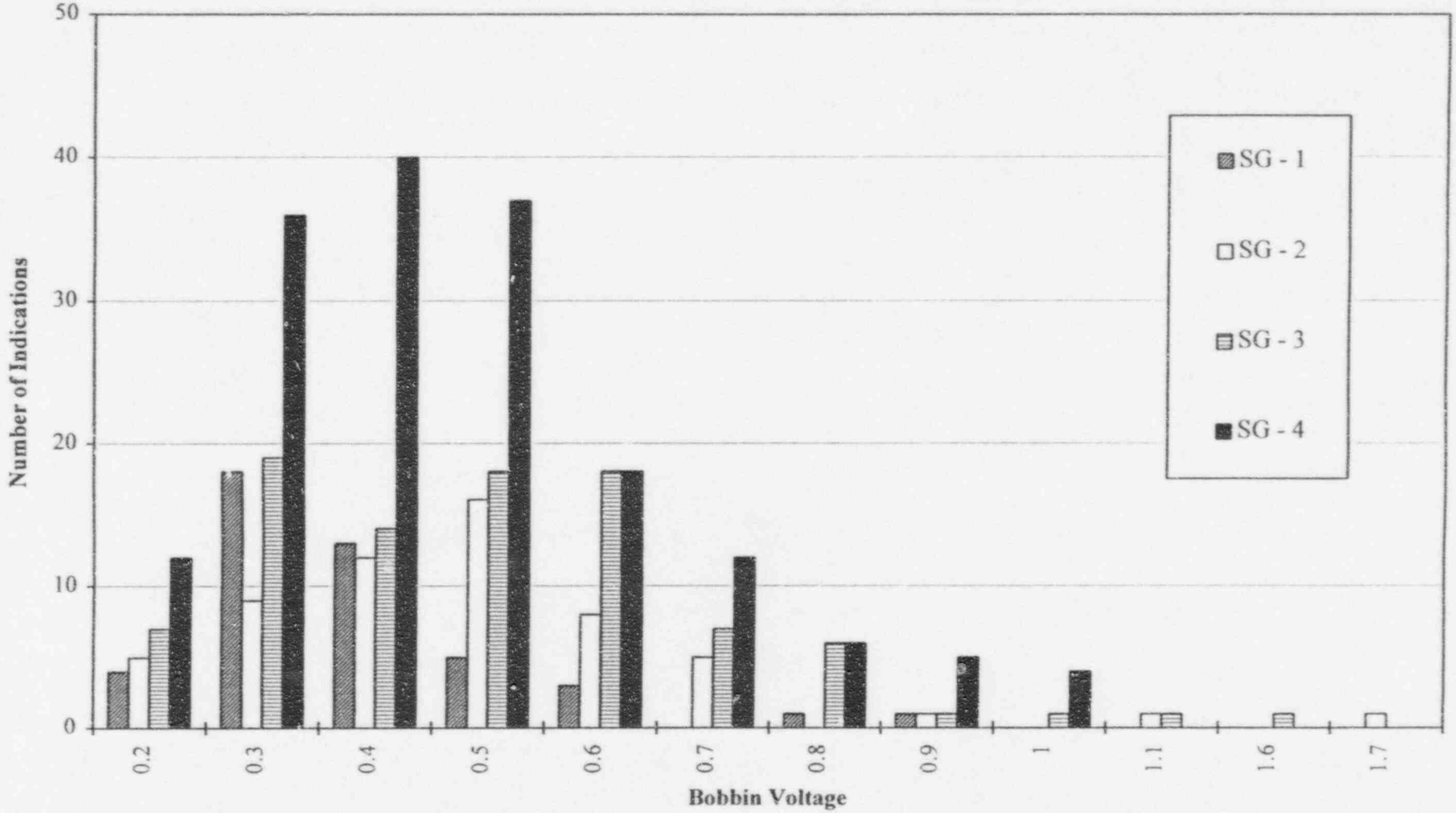

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Figure 4-2
Sequoyah Unit - 2 Ma, 1996 Outage
ODSCC Indication Axial Distributions for Tubes in Service During Cycle 7

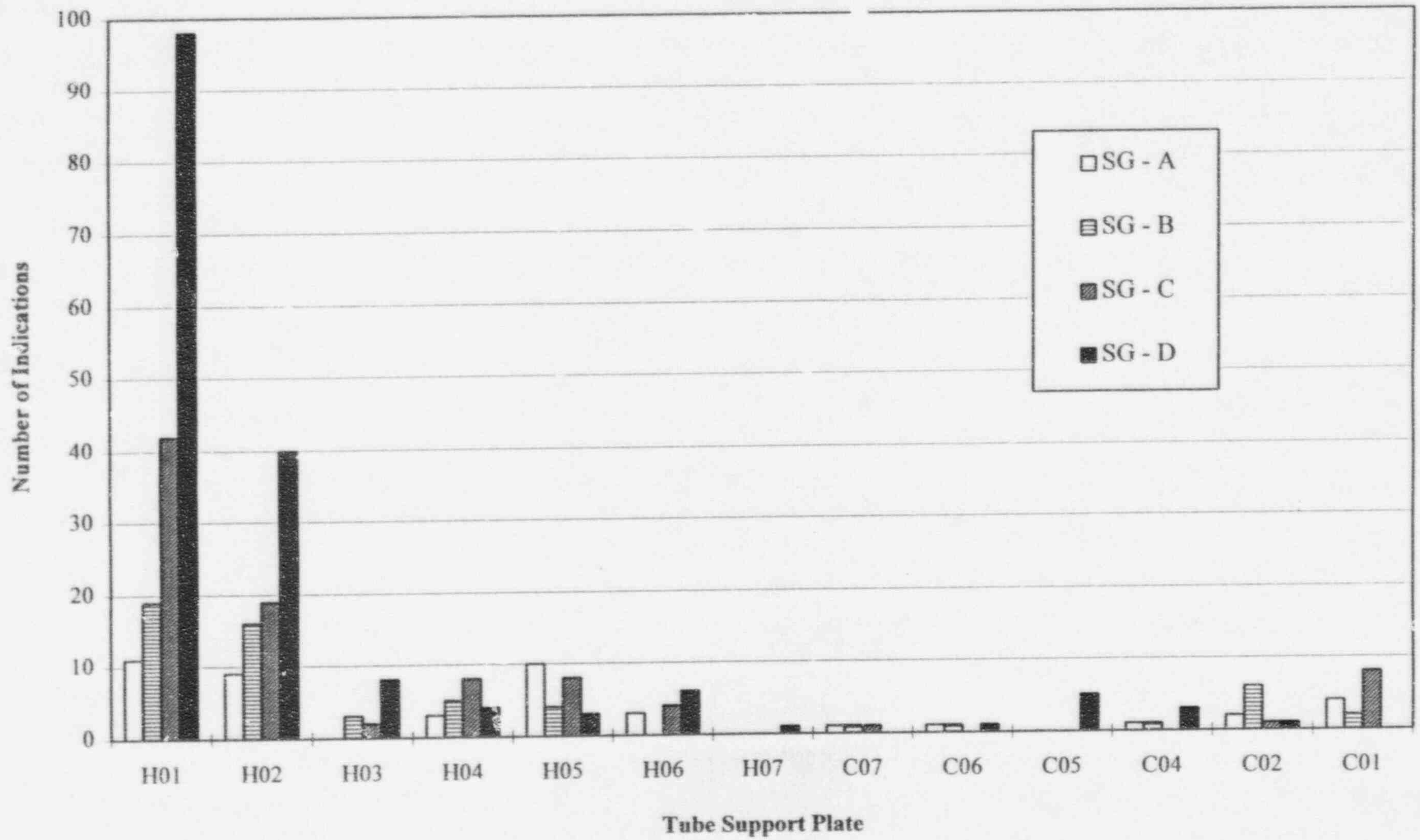

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Figure 4-3
Sequoyah Unit - 2 May 1996 Outage
Cumulative Probability Growth Rate Distributions for Cycle 7 on an EFPY Basis

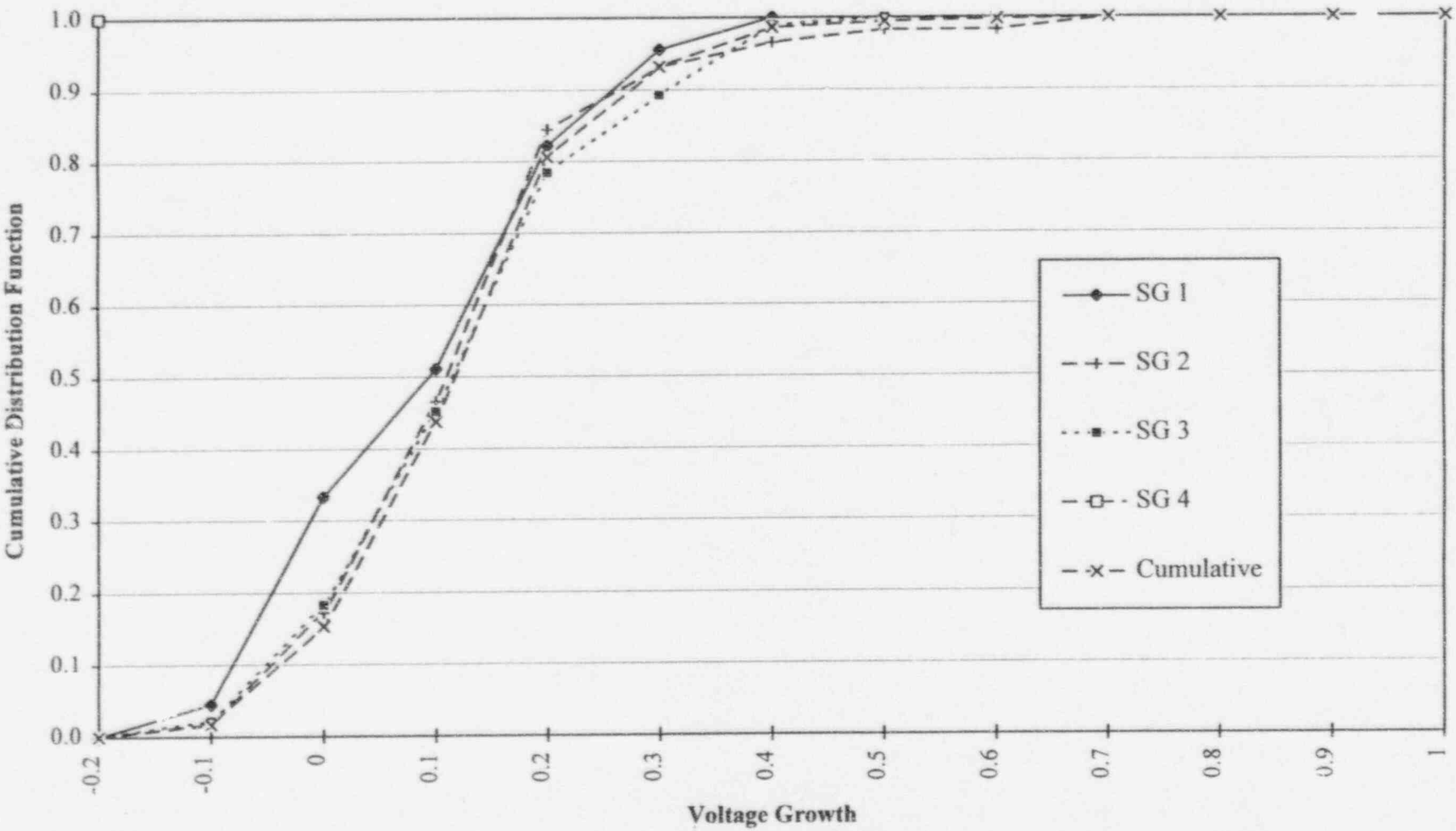

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Figure4-4
Sequoyah Unit 2, May 1996 Outage
Comparison of Cycle 7 Growth Rate Distribution (on an EFPY Basis) with Other Plants

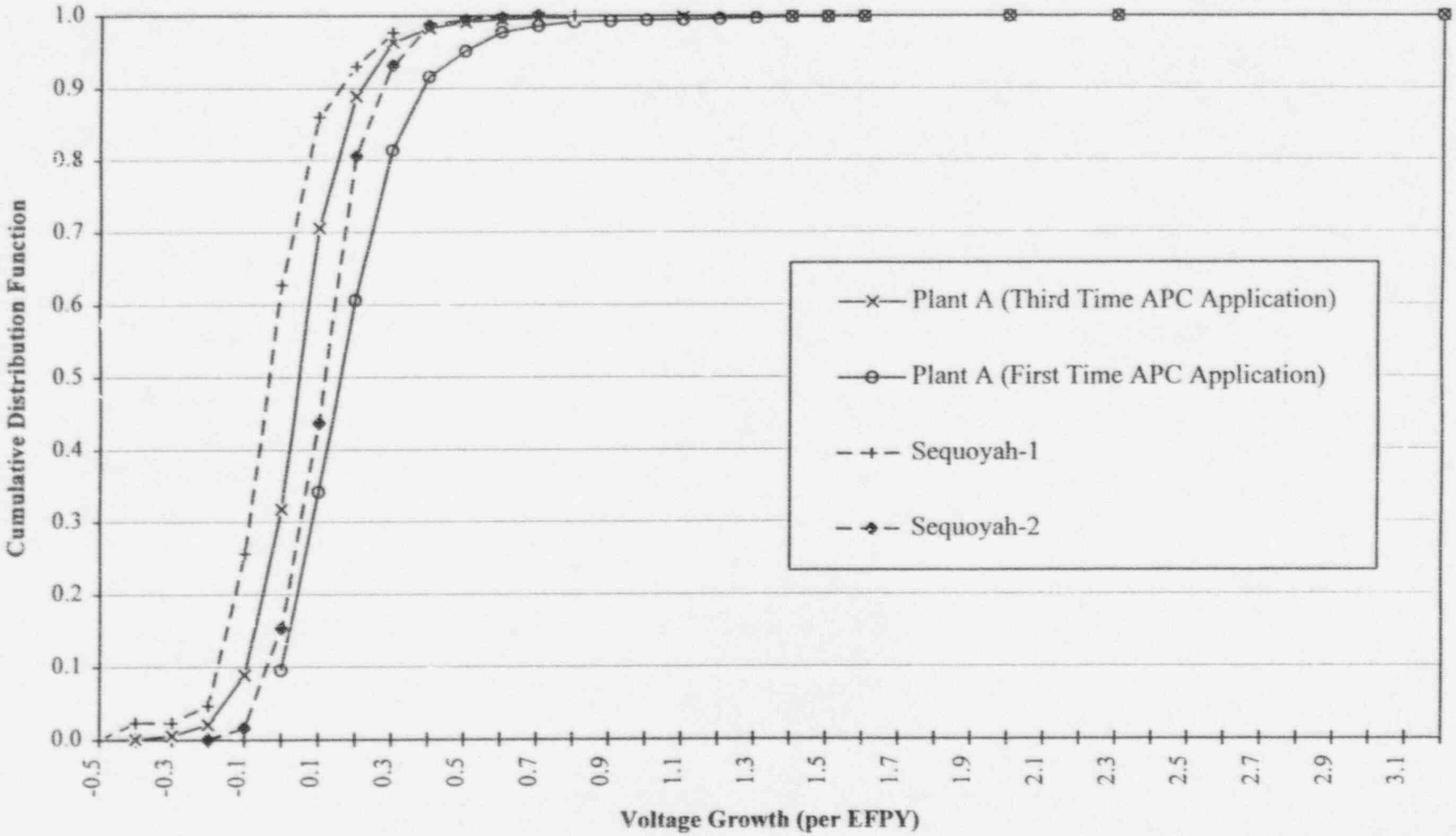

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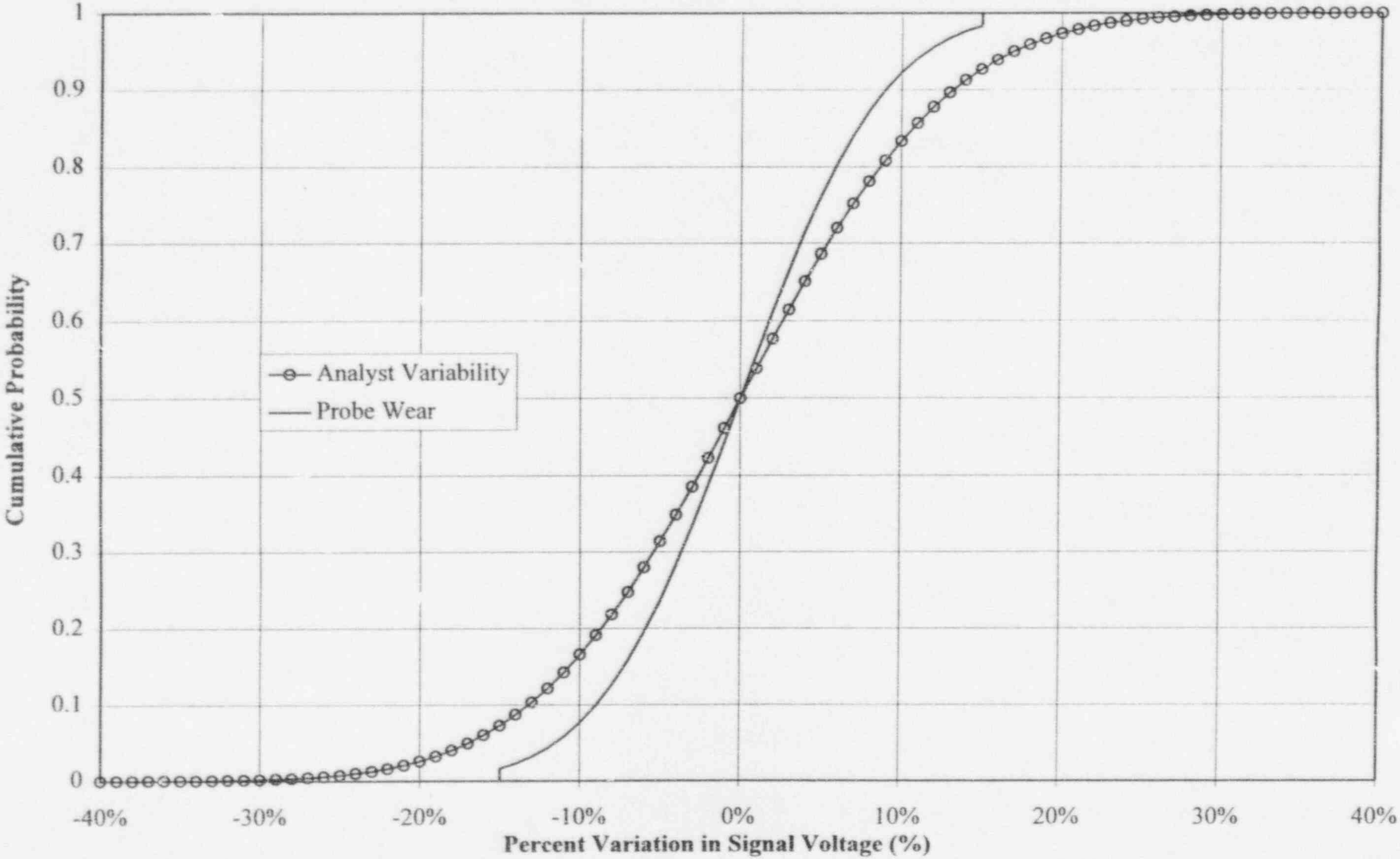
Figure 4-5
NDE Uncertainty Distributions



5.0 DATA BASE APPLIED FOR APC CORRELATIONS

The database used for the APC correlations applied in the analyses of this report are consistent with those used in the initial APC submittal for Sequoyah Units 1&2 (Reference 9.2) and 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. (The plant codes used are same as those established for Reference 9.4.) The updated database is given in Reference 9.6.

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 pulled during this outage (one from SG 3 - R8C60 and another from SG 2 - R4C23), 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 APC application, and it was concluded that inclusion of this Sequoyah Unit-2 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.

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 follows.

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

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.

There are no deplugged tubes returned to service at Sequoyah Unit-2 BOC-8.

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. Sufficient data exist now to define an alternate POD based on the past inspection data. A voltage-dependent POD known as POPCD has been established using data from 11 post-1992 inspections at 8 different plants. It takes into account newly initiated indications which are important for APC application. The development of POPCD and supporting data are presented in Reference 9.6. Table 7-3 shows POPCD data as a function of bobbin voltage and, in Figure 7-1, POPCD is compared with EPRI POD (EPRI POD is based on expert opinion and multiple analysts' evaluations for plants with 3/4" diameter tubes). It is evident from Figure 7-1 that below about 0.4 volt the NRC recommended POD of 0.6 is non-conservative while it is too conservative above about 0.5 volt. This is also reflected in the two BOC-8 distributions shown in Figure 7-1. It is of interest to apply POPCD for sensitivity analysis and compare the results for the case with a POD value of 0.6.

7.2 Calculation of Voltage Distributions

Bobbin voltage projections start with a cycle initial voltage distribution which is projected to the corresponding cycle final voltage distribution, based on the growth rate adjusted for the anticipated cycle operating time period. The overall growth rates for each of the Sequoyah Unit-2 steam generators during Cycle 7, as represented by their cumulative probability distribution functions, are shown on Figure 4-3. The composite growth data with 366 data points meet the Generic Letter 95-05 requirements. Further conservatism for the EOC-8 bobbin voltage prediction is provided by the use of the SG 2 growth rates as they are slightly higher than the composite growth rates. The methodology used in the calculations of EOC bobbin voltage distributions is described in Reference 9.5.

For each SG, the initial bobbin voltage distribution of indications being returned to service for the next cycle (BOC-8) is derived from the actual EOC-7 inspection results adjusted for tubes that are taken out of service by plugging. The Cycle 8 bobbin voltage population, summarized on Table 7-2, shows EOC-7 bobbin voltage indications, indications removed from service because of tube repairs (all below the 2 volts repair criteria) and the BOC-8 indications corresponding to two values of POD.

The estimated Cycle 8 operating period used in the EOC-8 voltage projection calculations is 457.0 EFPD.

7.3 Predicted EOC-8 Voltage Distributions

Using the Monte Carlo analysis methodology described in Section 6.0, analyses were performed to predict the performance of the Sequoyah Unit-2 steam generators at EOC-8, based on the BOC-8 conditions summarized in Table 7-2 and the SG 2 growth rates (limiting growth rates) shown in Table 4-3 . Calculations were carried out with a constant POD of 0.6, in accordance with the NRC direction of Reference 9.1 as well as POPCD. The results based on a POD of 0.6 are the reference values and those based on POPCD are intended for comparison with the reference results.

As shown in Figure 7-1, below about 0.4 volt NRC recommended POD of 0.6 is non-conservative relative to POPCD while it is too conservative above about 0.5 volt. Since a large fraction of the indications at EOC-7 are below 0.5 volt, the number of indications at BOC-8 predicted with POPCD is higher than that with a POD of 0.6, as seen in the two BOC-8 distributions shown in Table 7-2.

The EOC-8 predicted APC voltage distributions are summarized on Table 7-3. As anticipated, the limiting steam generator is SG 4 with about 283 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 7-2 through 7-5 for constant POD value of 0.6 as well as the voltage dependent POPCD. The maximum bobbin voltage predicted for EOC-8 is 2.3 volts for POD value of 0.6 and 2.2 volts for POPCD.

Table 7-1
Comparison of POPCD with EPRI POD
POPCD Based on Data from 11 Post-'92
Inspections in 8 Plants

Voltage Bin	EPRI POD	POPCD[#]
0.1	0.30	0.24
0.2	0.38	0.34
0.3	0.49	0.44
0.4	0.57	0.53
0.5	0.62	0.62
0.6	0.66	0.67
0.7	0.71	0.73
0.8	0.76	0.77
0.9	0.80	0.81
1	0.83	0.83
1.2	0.90	0.88
1.4	0.93	0.91
1.6	0.96	0.92
1.8	0.98	0.93
2	0.984	0.94
3	1.00	0.98
3.5	1.00	1.00

[#] Data Taken from Reference 9.6.

Table 7 - 2
Sequoyah Unit 2 May 1996
EOC-7 Field Bobbin and Assumed BOC-8 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

	Steam Generator 1				Steam Generator 2			
	EOC-7		BOC -8		EOC-7		BOC -8	
Voltage Bin	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	4	0	6.7	11.8	5	0	8.3	14.7
0.3	18	0	30.0	40.9	9	0	15.0	20.5
0.4	13	0	21.7	24.5	12	0	20.0	22.6
0.5	5	0	8.3	8.1	16	1	25.7	24.8
0.6	3	0	5	4.5	8	0	13.3	11.9
0.7	0	0	0	0	5	0	8.3	6.8
0.8	1	0	1.7	1.3	0	0	0	
0.9	1	0	1.7	1.2	1	0	1.7	1.2
1	0	0	0	0	0	0	0	0
1.1	0	0	0	0	1	0	1.7	1.2
1.2	0	0	0	0	0	0	0	0
1.3	0	0	0	0	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	1	0	1.7	1.1
Total	45	0	75.1	92.3	58	1	95.7	104.8
> 1V	0	0	0	0	2	0	1.7	2.3

	Steam Generator 3				Steam Generator 4			
	EOC-7		BOC -8		EOC-7		BOC -8	
Voltage Bin	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.2	7	0	11.7	20.6	12	0	20.0	35.3
0.3	19	0	31.7	43.2	36	0	60.0	81.8
0.4	14	0	23.3	26.4	40	0	66.7	75.5
0.5	18	0	30.0	29.0	37	0	61.7	59.7
0.6	18	0	30.0	26.9	18	0	30.0	26.9
0.7	7	0	11.7	9.6	12	0	20.0	16.4
0.8	6	0	10.0	7.8	6	0	10.0	7.8
0.9	1	0	1.7	1.2	5	0	8.3	6.2
1	1	0	1.7	1.2	4	0	6.7	4.8
1.1	1	1	0.7	0.2	0	0	0	0
1.8	0	0	0	0	0	0	0	0
1.3	0	0	0	0	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	1	0	1.7	1.1	0	0	0	0
1.7	0	0	0	0	0	0	0	0
Total	93	1	154.2	167.2	170	0	283.4	314.4
> 1V	2	1	2.4	1.3	0	0	0	0

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Table 7 - 3
Sequoyah Unit-2 May 1996
Voltage Distribution Projection for EOC - 8

Voltage Bin	Steam Generator 1		Steam Generator 2		Steam Generator 3		Steam Generator 4	
	Projected Number of Indications at EOC - 8							
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
0.2	0.69	1.23	0.87	1.53	1.21	2.14	2.08	3.67
0.3	5.40	8.17	4.19	6.71	7.08	11.05	12.82	19.82
0.4	13.09	17.96	9.19	12.87	15.27	21.42	31.15	42.74
0.5	16.69	21.49	14.68	18.02	21.67	27.30	46.98	58.15
0.6	14.95	17.99	17.45	19.16	25.15	28.02	51.39	57.91
0.7	9.76	10.92	16.35	16.60	24.17	24.36	44.15	45.78
0.8	5.67	6.02	12.30	11.85	20.41	19.28	32.59	31.65
0.9	3.37	3.41	7.72	7.19	14.69	13.29	22.25	20.50
1.0	2.14	2.09	4.46	4.06	9.45	8.27	15.11	13.34
1.1	1.45	1.40	2.63	2.36	5.77	4.95	10.21	8.78
1.2	0.78	0.62	1.68	1.45	3.39	2.83	6.61	5.56
1.3	0.00	0.00	1.11	0.93	1.94	1.54	3.91	3.21
1.4	0.70	0.70	0.70	0.56	1.14	0.87	2.09	1.68
1.5	0.30	0.30	0.43	0.33	0.70	0.52	1.00	0.55
1.6			0.31	0.22	0.49	0.31	0.00	0.00
1.7			0.29	0.05	0.40	0.00	0.70	0.70
1.8			0.30	0.00	0.07	0.70	0.30	0.30
1.9			0.01	0.70	0.00	0.00		
2.0			0.00	0.00	0.70	0.00		
2.1			0.70	0.00	0.30	0.30		
2.2			0.00	0.30				
2.3			0.30					
TOTAL	74.99	92.30	95.67	104.89	154.00	167.15	283.34	314.34
> 1 V	3.23	3.02	8.46	6.90	14.90	12.02	24.82	20.78
> 2 V	0	0	1.00	0	1.00	0.30	0	0

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Figure 7-1
Comparison of POPCD with EPRI POD
POPCD Based on Data from 11 Inspections at 8 Plants

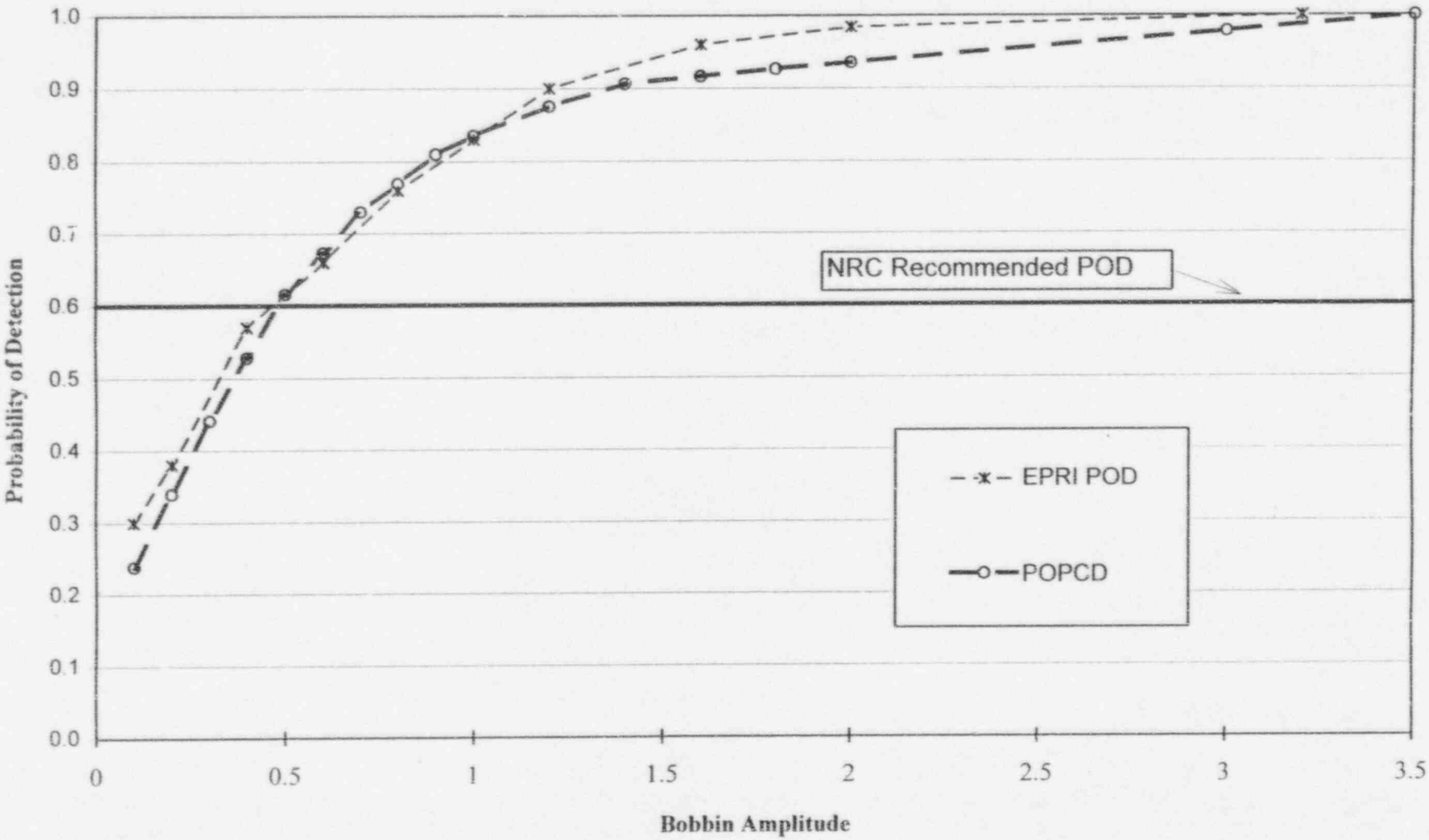
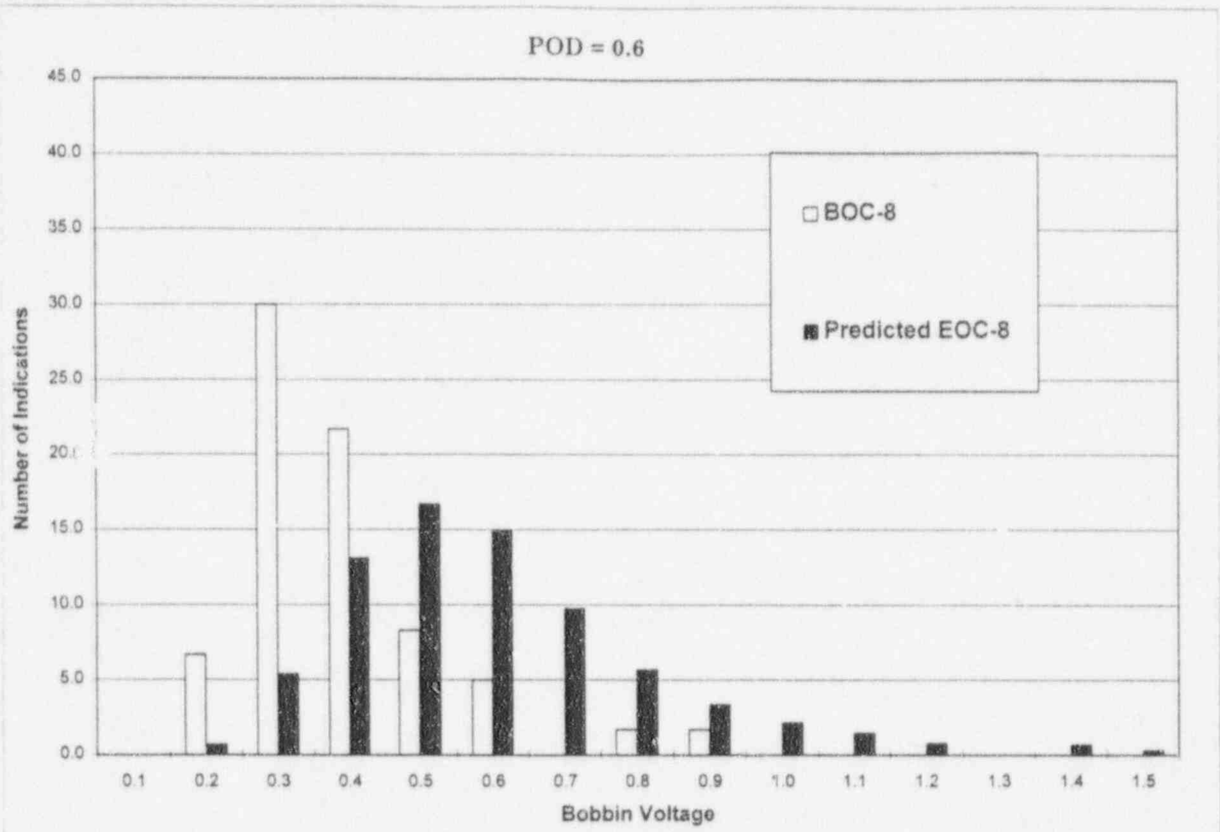


Figure 7-2
Sequoyah Unit-2 SG 1
Predicted Bobbin Voltage Distribution for Cycle 8



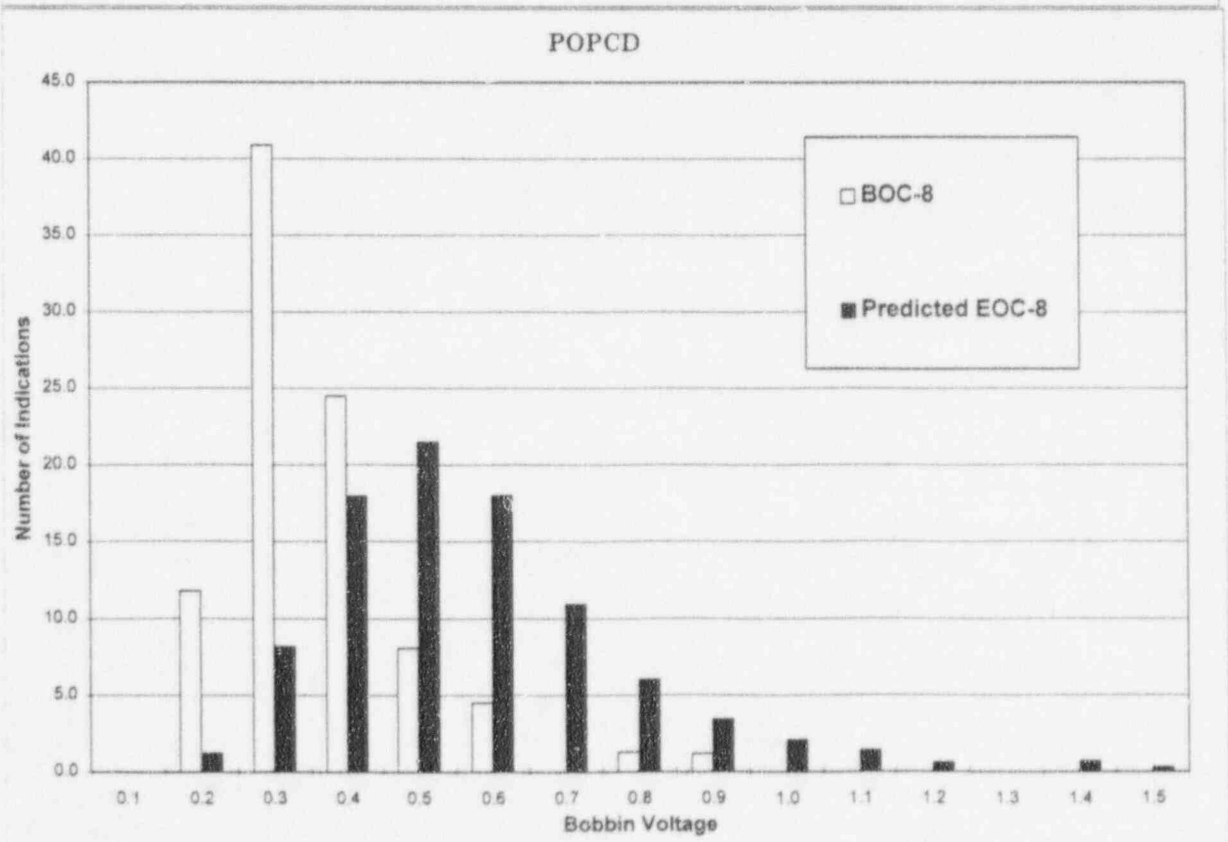


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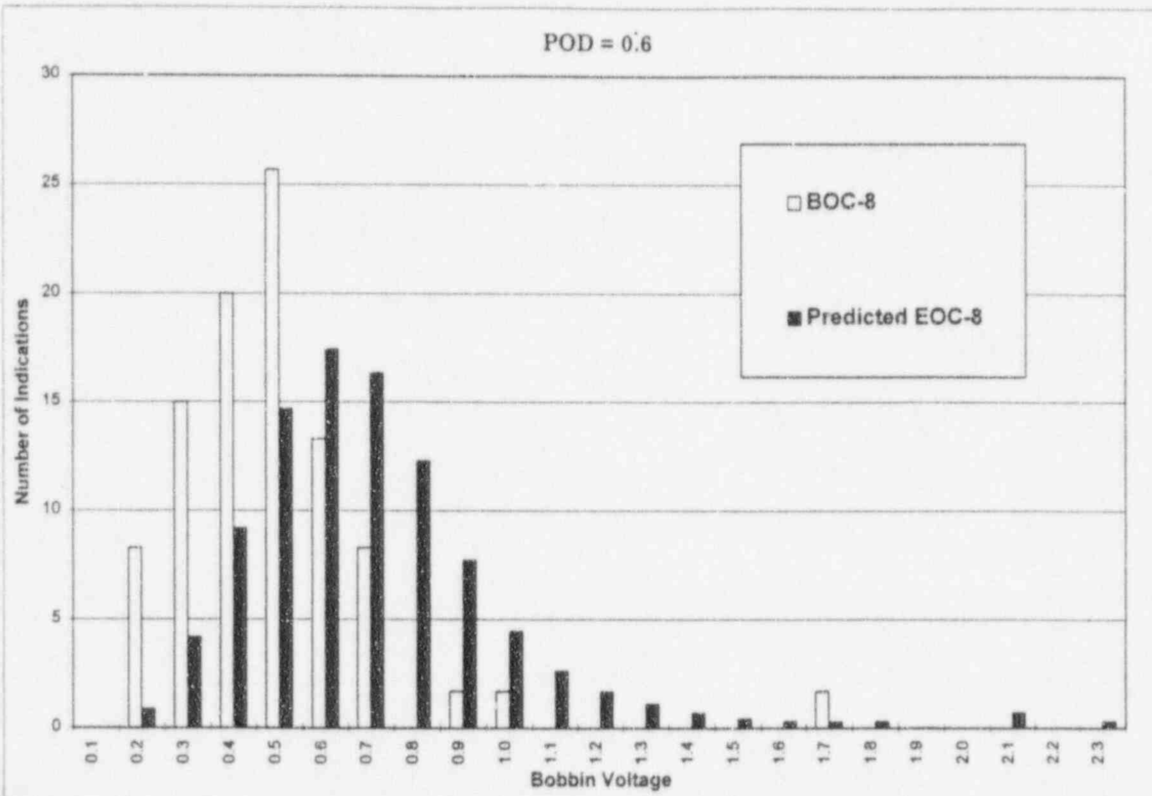
Figure 7 - 3
Sequoyah Unit-2 SG 2
Predicted Bobbin Voltage Distribution for Cycle 8



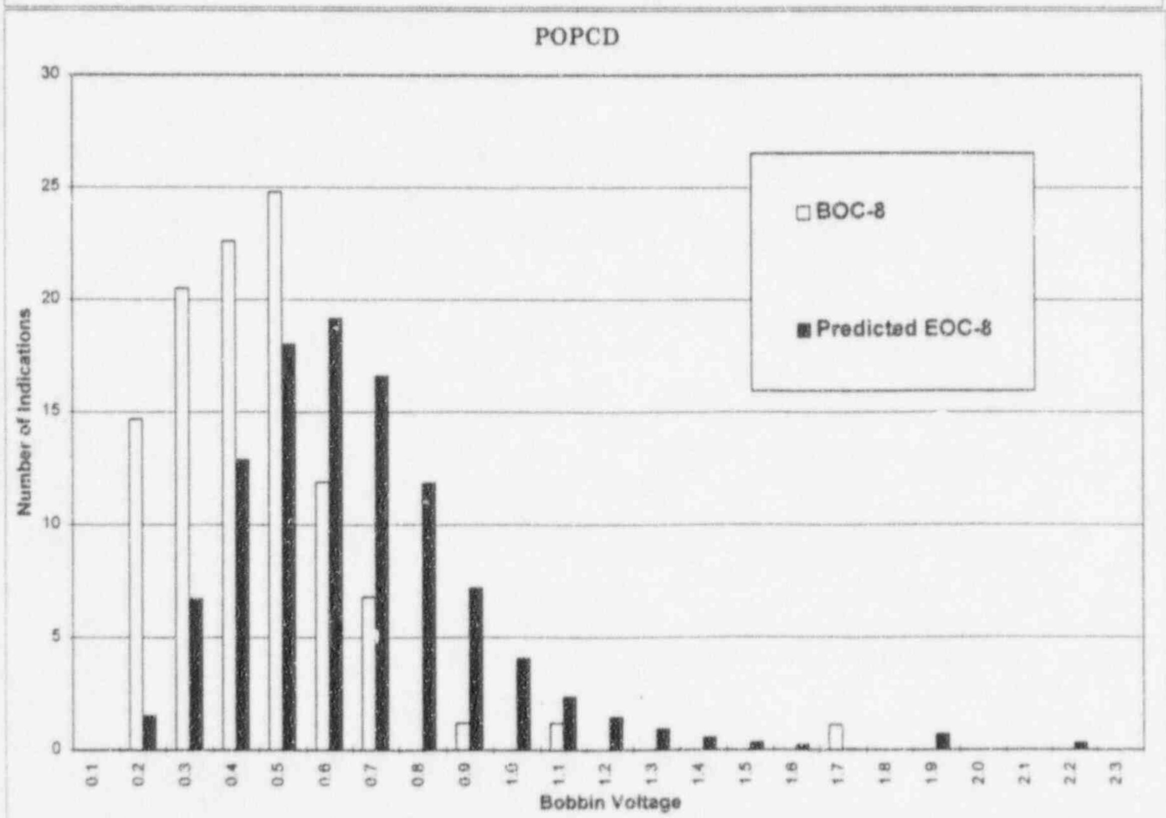


Figure 7 - 4
Sequoyah Unit-2 SC 3
Predicted Bobbin Voltage Distribution for Cycle 8

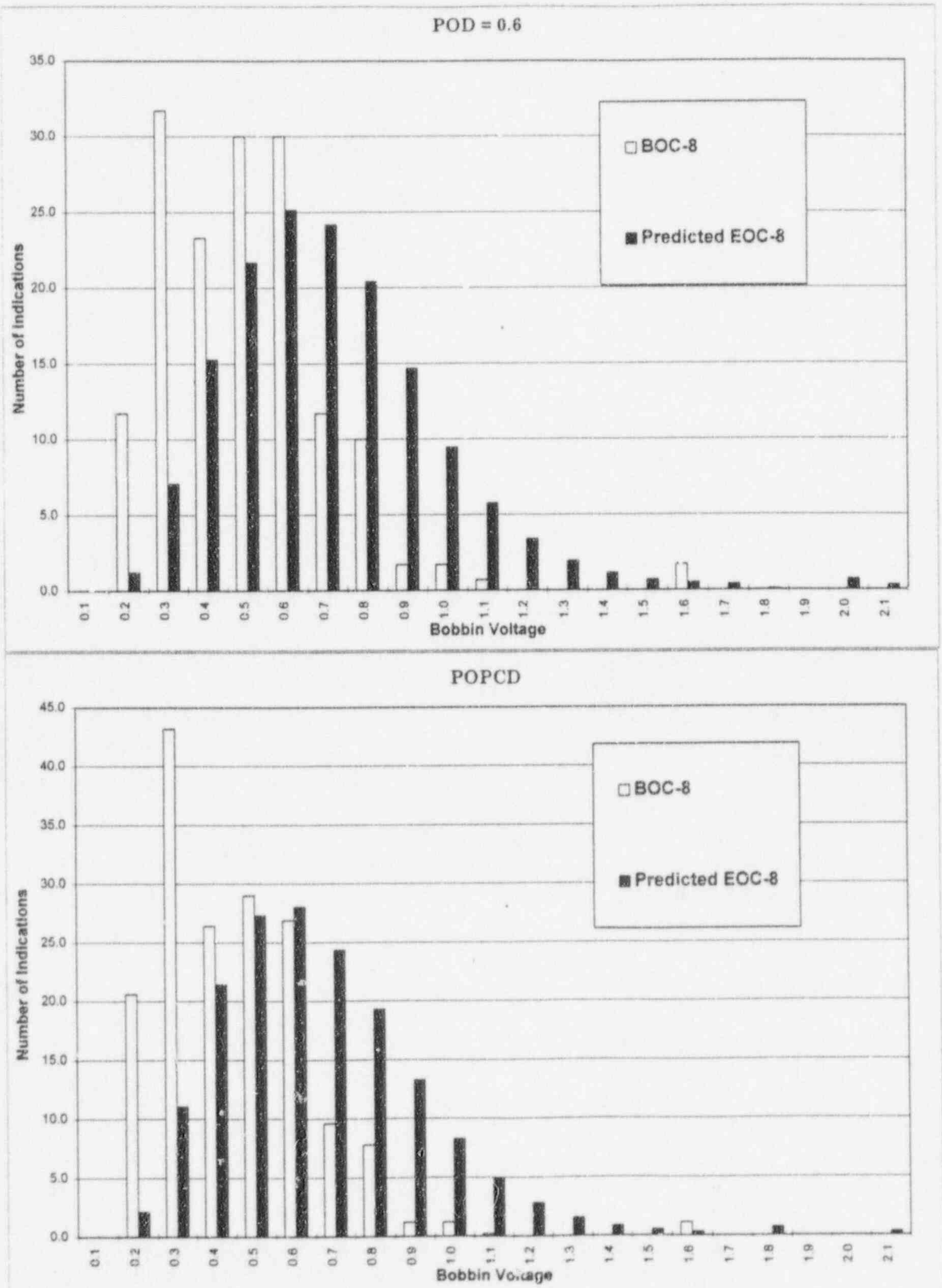
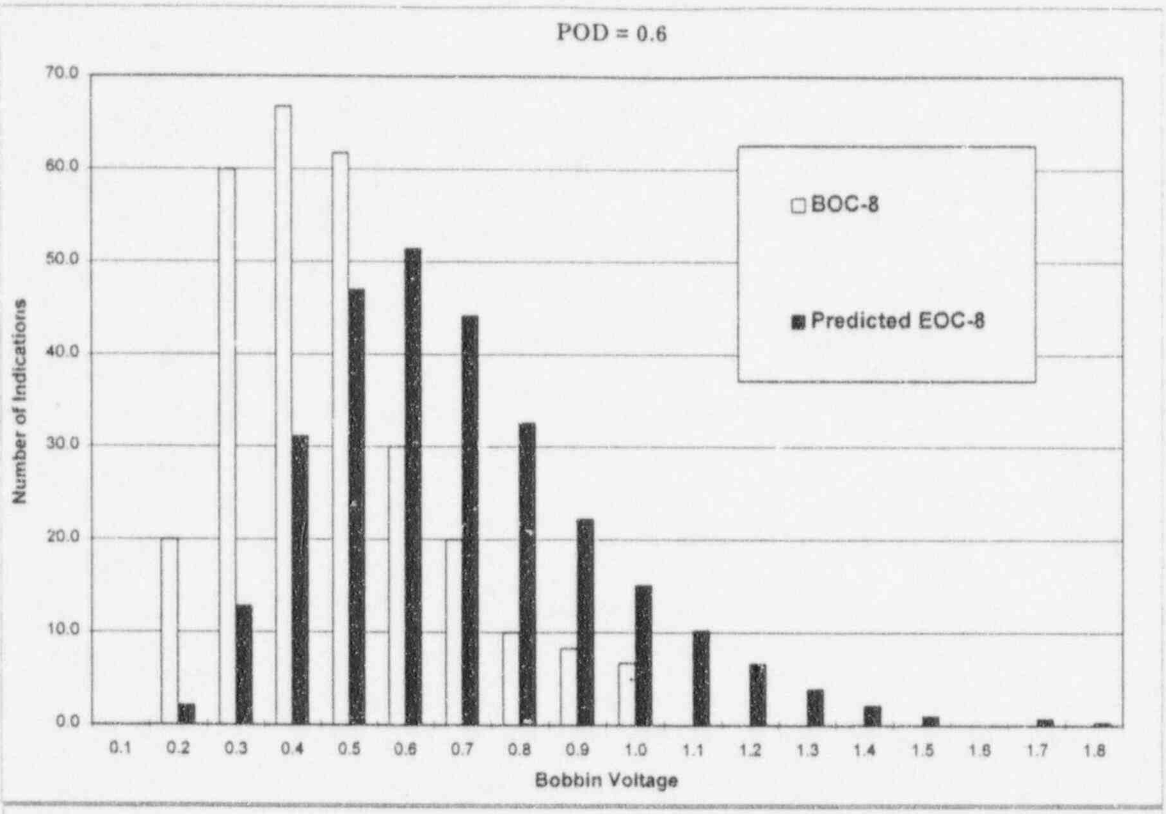
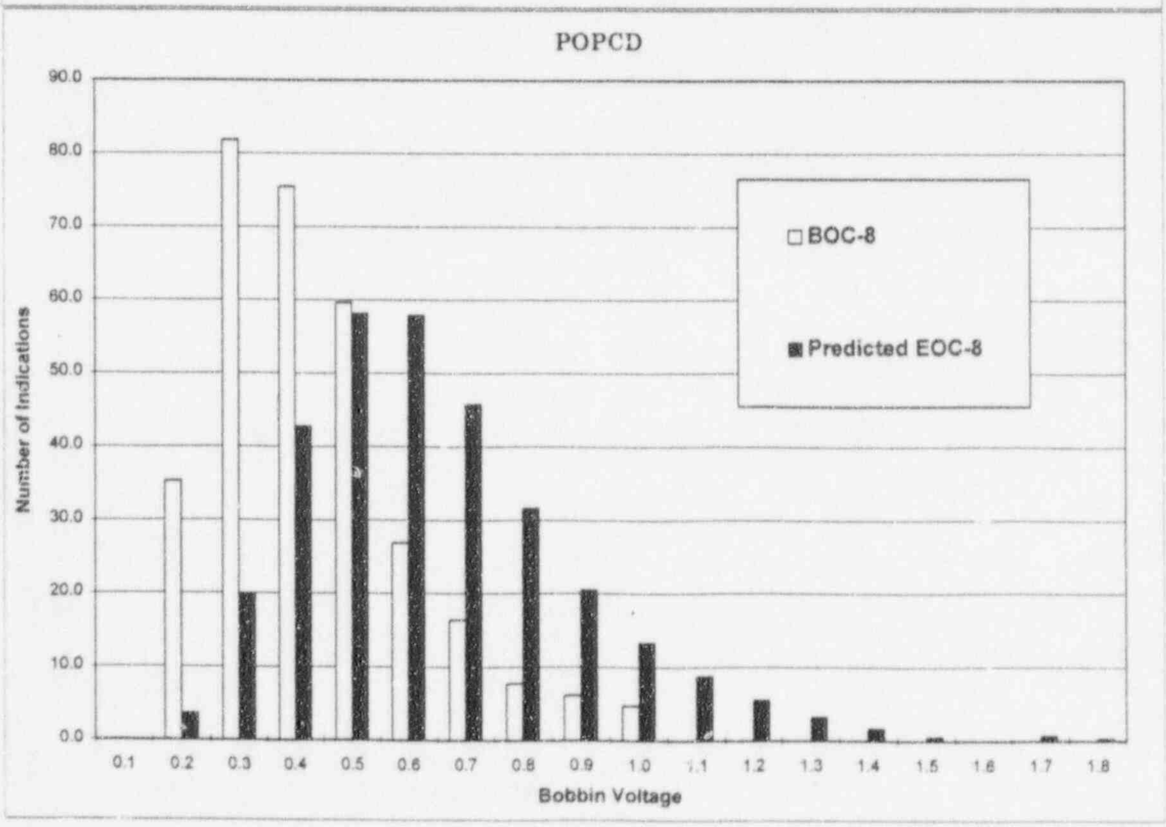


Figure 7 - 5
Sequoyah Unit-2 SG 4
Predicted Bobbin Voltage Distribution for Cycle 8





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 Monte Carlo analysis methodology described in Section 6.0, 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. Since APC is being applied for the first time, no Monte Carlo projections are available for EOC-7 conditions, so a comparison of actuals with projections is not possible.

From Table 8-1 it is evident that SG 4 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 0.07 gpm and 1.90×10^{-5}, respectively. The corresponding results projected for EOC-8 condition using the NRC required POD value of 0.6 are 0.19 gpm and 1.90×10^{-5}. The results for both EOC-7 and EOC-8 conditions are well below the Sequoyah Unit-2 allowable SLB limit of 3.7 gpm and the NRC reporting guideline for tube burst probability of 1.0×10^{-2}. Although a larger EOC-8 indication population is predicted with POPCD, the peak voltages and SLB leak and burst results predicted are lower than those with a POD of 0.6. In summary, the Sequoyah Unit-2 steam generators meet and exceed the APC criteria with a substantial margin.

Table 8 -1 Sequoyah Unit-2 1996 Outage Summary of SLB Tube Leak Rate and Burst Probability						
Steam Generator	POD	No. of Indic-ations	Max. Volts#	Burst Probability		SLB Leak Rate gpm
				1 Tube	≥ 1 Tube	
EOC-7 Actual						
1	1	45	1.1	1.90×10^{-5}	$< 4 \times 10^{-6}$	<0.01
2	1	58	2.0	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.01
3	1	93	1.9	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.04
4	1	170	1.4	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.07
EOC-8 Predicted						
1	0.6	75	1.5	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.03
	POPCD	92	1.6	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.03
2	0.6	96	2.3	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.10
	POPCD	105	2.2	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.09
3	0.6	154	2.1	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.19
	POPCD	167	2.1	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.17
4	0.6	283	1.8	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.35
	POPCD	314	1.8	1.90×10^{-5}	$< 4 \times 10^{-6}$	0.34

#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.

9.6 Addendum to EPRI Report NP-7480-L, "Steam Generator Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Criteria, Addendum-1, 1996 Database Update" August 1996.

Attachment 2

Westinghouse Electric Corporation
Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

TVA-96-138
Ref: TVA-96-129

July 29, 1996

Mr. Mark Burzynski
Tennessee Valley Authority
Sequoyah Nuclear Plant
P.O. Box 2000
Soddy Daisy, TN 37379

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT
S/G Tube Integrity Assessment - Revision

Dear Mr. Burzynski:

Attached please find revised Unit 2 S/G Tube Integrity Assessment for U-Bend Axial PWSCC Indications.

This revision includes changes discussed between Westinghouse and TVA (D. Hughes).

If you have any questions, please contact the undersigned.

Very truly yours,

R.D. Agostino for

David R. Collier
Project Director
TVA Projects

cc: D. Lafever
D. Hughes, BR-3A-C
D. Goetcheus, BR-3A-C
E. Camp
F. Fink

Sequoyah-2 1996 Inspection
SG Tube Integrity Assessment for U-Bend Axial PWSCC Indications

1.0 Introduction

This report provides a tube integrity assessment for axial PWSCC indications found in the small radius U-bend region of Sequoyah-2 in the 1996 inspection. The axial indications are dominantly in the Row 1 tubes with only one shorter indication in Row 2 which is judged not to be a real indication but conservatively plugged. The inspection was performed with an 80 mil RPC pancake coil with confirmation of the indications including inspection with a + Point coil. The + Point coil helps to reduce ovality and liftoff responses in the U-bend and permits improved sizing of the indications.
The field data analyses included a review of the prior '94, 80 mil coil inspection data for indications found in '96. These results permit comparisons of the prior and current inspection results and provide estimates of growth in length and maximum RPC voltage. To support this tube integrity assessment, crack depth profiles for the three longest indications were estimated from the + Point inspection results. The depth profiles permit estimates of the burst capability of the indications.

2.0 Operating Conditions for Structural Assessment

The U-bend indications are free span indications and the structural margin guideline of RG 1.121 to accommodate $3\Delta P_{NO}$ pressure differential is applicable. The steam pressure for Sequoyah-2 is about 831 psi which results in ΔP_{NO} = 1419 psi and $3\Delta P_{NO}$ = 4257 psi. Predicted burst pressures for the U-bend indications are compared to the 4257 psi guideline for the structural integrity assessment.

3.0 Material Properties for Small Radius U-bend Tubes

Burst pressure analyses given later in this report require the material flow stress. For small radius U-bends, the strain hardening from bending of the tubes significantly increases the yield strength of the tubing. Material properties from tube manufacturing data are taken from straight length sections of the tubing and would underestimate the material properties. As discussed below, the increase in properties from tube bending is only partially reduced by the U-bend heat treatment such as applied at Sequoyah-2.

The material properties of Row 1 tubes were evaluated as a part of the U-bend heat treatment process development. As-received U-bends indicated a yield strength of about 105 ksi. A stress relieved U-bend indicated a yield strength of about 97 ksi after one cycle of heat treatment and about 90 ksi after two, five minute cycles at 1500 °F. Only a single heat treatment is applied in the field process such that the yield strength after heat treatment would be expected to be about 95 ksi. The tensile strength is estimated at about 120 ksi and the test data indicates that heat treatment to 1500 °F has little effect on the ultimate tensile strength. Thus, the flow strength would be expected to be > 105

ksi following U-bend heat treatment. For the burst pressure estimates of this report, a flow stress of 100 ksi is applied. The material certifications from the manufacturing records show flow stress of 80 to 85 ksi for the straight length tubing of the three tubes analyzed in this report.

The burst pressure correlations used for Alloy 600 tubing were developed for the more ductile range of flow stresses and are known to slightly overestimate burst pressures for strain hardened tubing with flow stresses as high as 100 ksi. The burst pressures for the U-bend tubes analyzed would exceed that calculated for the straight length material properties and be less than that calculated for a 100 ksi flow stress. Therefore, burst pressures are reported for both the material certification properties and a flow stress of 100 ksi.

4.0 U-bend Inspection Results

A total of 19 U-bend ID axial indications were reported in the '96 inspection. Table 1 provides a summary of the indications as obtained from analysis of the RPC pancake coil. Table 1 was obtained from a growth study and also includes a reanalysis of the '94 cycle 6 inspection results for axial length and maximum voltage. The circumferential extent of the indications is also given in the table and represents a measure of the coil resolution as influenced by coil liftoff and permeability effects. A TVA review of the data indicates that the coil responses are significantly influenced by permeability effects particularly for the cycle 6 data. Although the cycle 7 data are appreciably better than the cycle 6 data with regard to the permeability variations, there is still a permeability influence which makes length measurements difficult.

It is seen from Table 1 that there is no significant change in crack length from the pancake coil between the '96 results and the reevaluated '94 data. In some cases, the increase in voltage, indicating a potential increase in depth, may be real although there are a number of indications with a decrease in voltage between the '94 and '96 inspections. The results clearly show that the indications were present in '94 at comparable lengths to that in '96 and growth, if any, was principally in depth. Thus, the indications did not initiate over the last operating cycle and growth rates, while not adequately quantifiable, are modest for the U-bend indications. The indications have been present for some time and the current inspection results are typical of an "inspection transient" resulting from improvements in the mag biased coils.

The three longest indications are R1C27 and R1C38 in SG 3 and R1C23 in SG 4. These indications have been further evaluated as a part of this study. Demonstration of tube integrity for these indications bounds the other indications since these three indications have both the longest lengths and the highest maximum voltages. In addition, the next longest indication of 0.54" would satisfy the $3\Delta P_{NO}$ burst margin for a tube with a flow stress of 100 ksi even if the crack were assumed to be throughwall. Thus, it is adequate to focus the tube integrity assessment on the three largest indications.

The pancake coil '96 and '94 responses from the field analyses for the three largest indications are shown in Figures 1 to 6. These results show the same general shape of the indications between the '94 and '96 inspections as indicated by the Table 1 results.

The pancake coil response of R1C38 is of particular interest since it shows as series of potential indications spanning an overall length of about 4 inches. This is shown by the laboratory reanalysis of the pancake coil data as given in Figure 7. Figure 7 shows at least six separable coil responses. It is believed that only a part of the largest amplitude response (right side of Figure 7) represents a real flaw. This is supported by the laboratory analysis of the + Point data as shown in Figure 10. The + Point coil subtracts common responses from the two coils which helps to reduce effects of liftoff and permeability. It is seen from the + Point data of Figure 10 that there is only one significant response spanning a length of about 0.78". The + Point data is used for the tube integrity assessment discussed later in this report. The + Point response for R1C27 is similar to that found for the pancake coil as seen by a comparison of Figures 1 and 9.

The longest reported indication is that for R1C23 in SG 4. Figures 5 and 8 show the field and laboratory analyses of the pancake coil data for this indication. There is no significant difference between the two analyses. Figures 11 and 12 show analyses of the + Point data for two different views of the indication for comparison with the pancake coil results of Figures 5 and 8. The + Point data shows an offset of the indication at about the mid-length of the response which is only slightly seen in the pancake response of Figure 8. This effect is believed to be likely due to slippage in the probe and the indication is assumed to be a continuous axial crack for the tube integrity analyses. The low amplitude, rounded + Point responses near the ends of the indication are not believed to be due to a real crack. For conservatism, the tube integrity analyses are performed with and without the ends of the response included as the flaw length.

5.0 Tube Integrity Assessment

The crack lengths of Table 1 for tubes R1C27, R1C38 and R1C23 are too long to establish tube integrity based on a very conservative throughwall crack assumption. For a flow stress of about 100 ksi, a throughwall crack length on the order of 0.55 to 0.60 inch would approximate the structural limit for a throughwall indication. Therefore, the tube integrity assessment for these three largest indications is based on depth sizing for the indications. For small radius U-bend indications, the phase angle response is distorted by liftoff effects due to tube ovality and by permeability effects. These effects are particularly significant for pancake coils but are reduced for the + Point coil. Therefore, only the + Point inspection results have been used to develop crack depth as a function of length. Some distortion remains in the + Point phase angle and it is necessary to conservatively assign depths by using the phase angle corresponding to the deepest depth in analyzing the distorted phase response. Thus, the depth profiles are expected to be an overestimate of the actual depth and result in a conservative tube integrity assessment. The + Point data, as well as a reanalysis of the pancake coil data, were performed in the laboratory to support this tube integrity assessment.

Table 2 summarizes a comparison of the field calls, the growth study of Table 1 and the laboratory reanalysis results. The laboratory + Point analyses include the average depth and calculated burst pressure as discussed below. As previously noted, the tails of the coil responses are not expected to represent a crack but were conservatively included in the + Point responses for the tube integrity assessment. This results in the laboratory crack lengths tending to exceed the field calls. The conservatively estimated average depths for

the indications range from 62.9% for R1C38 to 68.7% for R1C23.

The crack length vs depth profiles were used to estimate the burst pressure capability for the indications. The results for the three potentially limiting indications are given in Tables 3 to 5. The burst pressure analysis methodology searches the crack profile for the most limiting length/depth section that results in the lowest burst pressure (weak link using BKH model column in the tables) as well as calculating the burst pressure for the total crack length and average depth. The tables also include a plot of the crack depth profile as obtained from the + Point analyses. For all three indications, the lowest burst pressure results over a section of the crack as determined by the weak link model. For R1C27, the estimated burst pressure is 5.07 ksi which provides significant margin over the RG 1.121 guidelines. The crack length between 0.16" and 1.05" contributes to limiting the burst pressure of the indication. While recognizing that this estimate may be slightly high due to the low ductility in the U-bend, there is ample margin for uncertainty in the burst pressure analysis. Even if material properties are very conservatively assumed to correspond to the straight length material certification, the burst pressure would be 4.081 ksi which is near to the structural requirement. For R1C38, the estimated burst pressure of the indication is 7.39 ksi and this indication is the least limiting of the three indications. The estimated burst pressure for R1C23, the estimated burst pressure is 5.04 ksi with the weak link of the crack occurring between 0.03" and 1.24" of the crack length. The burst pressure would be 4.23 ksi even for the very conservative application of the straight length material properties. The expected real crack length (+ Point Run 2 of Table 5) results in a burst pressure of about 5.7 ksi.

The maximum depth estimates of Table 2 for R1C27 in SG 3 and R1C23 in SG 4 could have short throughwall crack penetration within the uncertainties of the depth estimates. Operating leakage in these SGs was only a few gpd with the source of the leakage not clearly identified. The crack profiles of Tables 3 and 5 indicate that the potential throughwall length would be about 0.2" and conservatively < 0.3". For a 0.3" throughwall U-bend crack, the operating leakage would be about 0.01 gpm (about 15 gpd) and the SLB leakage would be about 0.06 gpm (about 90 gpd). These small leak rates do not challenge leakage integrity for the Seqouyah-2 SGs.

6.0 Conclusions

Based on the above assessments, it is concluded that:

- The U-bend indications found in the 1996 Sequoyah-2 inspection satisfy the structural and leakage requirements of Reg. Guide 1.121.

- The burst pressures for the U-bend indications exceed about 5 ksi compared to the RG 1.121 guideline of 4.257 ksi.
  - The burst assessment includes conservative estimates of crack length and depth.

- Steamline break accident condition leakage would be expected to be < 90 gpd which is insignificant compared to allowable leakage under accident conditions.

Table 1. Summary of U-Bend Indication Growth Assessment Results - Pancake Coil

5/23/96

S/G	ROW	COL	LOCN	AXIAL EXTENT		CIRC EXTENT		VOLTAGE		PVN INFLU	FLAW ORIEN.
				CY 6	CY 7	CY 6	CY 7	CY 6	CY 7		
2	2	21	H07+8.0	NDD	.22	NDD	57	NDD	1.93		AXI
	1	23	H07+2.7	.27	.33	68	37	8.37	10.21	YES	AXI
	1	33	H07+2.7	.35	.28	63	27	2.12	6.15	YES	AXI
	1	34	H07+2.6	.33	.33	58	40	5.20	4.35	YES	AXI
	1	40	H07+2.6	.41	.33	157	81	13.96	9.71	YES	AXI
	1	48	H07+7.2	.37	.47	63	49	23.77	21.04	YES	AXI
	1	48	H07+7.2	.33	.33	55	42	8.02	3.01	YES	AXI
3	1	2	H07+7.7	.44	.38	65	65	3.68	7.44	YES	AXI
	1	26	H07+4.3	.50	.54	55	62	2.49	12.30	YES	AXI
	1	27	H07+6.5	.71	.91	66	57	2.87	21.89	YES	AXI
	1	29	H07+3.8	.56	.52	52	59	11.60	8.96	YES	OBL
	1	29	H07+3.5	.56	.47	58	59	14.37	6.59	YES	OBL
	1	38	H07+6.9	1.20	.90	105	95	11.40	18.01	YES	AXI
	1	50	H07+7.5	.39	.39	71	91	5.63	8.97	YES	AXI
	1	59	H07+7.5	.18	.20	38	75	3.66	10.13	YES	AXI
4	1	15	H07+6.9	.56	.34	90	30	7.17	3.81	YES	AXI
	1	17	H07+6.5	.48	.38	105	44	10.08	11.22	YES	AXI
	1	19	H07+6.5	.35	39	59	49	5.91	4.66	YES	AXI
	1	23	H07+6.4	1.41	1.35	75	47	17.00	28.58	YES	AXI

**Table 2. Sequoyah-2 '96 Inspection: Summary of U-bend RPC and Burst Pressure Analyses
Three Largest Indications**

SG	Tube	Elev.	Coil	Anal.	'96 Inspection					'94 Inspection	
					Length (in.)	Max. Volts	Max. Depth	Avg. Depth	Burst Press. (ksi)	Length (in.)	Max. Volts
3	R1C27	7H+3.7	80 Mil	Field	0.76	24.9					
		7H+3.8	+ Pt	Field		4.75					
		7H+6.5	80 Mil	Growth	0.91	21.9				0.71	2.87
			80 Mil	Lab.	0.77	15.8	84%				
			+ Pt	Lab.	1.42	4.30	100%	66.5%	5.07(1) 4.08(2)		
3	R1C38	7H+6.3	80 Mil	Field	4.41(3)	10.1					
		7H+6.4	+ Pt	Field	0.26	5.21					
		7H+6.9	80 Mil	Growth	0.90	18.0				1.20	11.4
			80 Mil	Lab.	0.70	11.1	85%				
			+ Pt	Lab.	0.78	4.15	84%	62.9%	7.39(1) 6.30(2)		
4	R1C23	7H+6.5	80 Mil	Field	1.35	28.2					
		7H+6.4	+ Pt	Field		7.09					
		7H+6.5	80 Mil	Growth	1.35	28.6				1.41	17.0
			80 Mil	Lab.	1.68	17.9	100%				
			+ Pt	Lab.	1.70	4.44	99%	68.7%	5.04(1) 4.23(2)		

Notes:
1. Flow stress of 100 ksi at R.T. based on material hardening due to bending of tube followed by U-bend heat treatment.
2. Flow stress based on tube material certifications for straight length of tube.
3. Total reported length spans a number of individual 80 mil coil responses, most of which are not flaw like in + Point coil inspection (See Figure 7)

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Table 3: Sequoyah-2, SG-3; Tube R1C27 U-bend Axial Crack; +Point Data

OD	t	Rm	Pfsbp			Sf.RT2OP	Sf.cert	
0.875	0.050	0.4125	14326			0.9114	73.37	Op. Temp.
Pbar2Pb	P0	P.p	P.s	dP.nop	dP.slb	Sf.str.hard	80.50	Rm. Temp.
0.000	0.000	2.250	0.831	1.419	2.560	91.14	Op. Temp	
						100.00	Rm Temp	
+Point						+Point		
Crack Depths	Lengths	Crack Depths	Lengths	Crack Depths	Lengths	Weak Link Using BKHmodel		
0%	0					X.min	0.160	
22%	0.03					X.max	1.050	
52%	0.06					Length	0.890	
60%	0.1					Depth	80.1%	
55%	0.13					Pb / Sf	0.056	
65%	0.16					Pb.str. hard	5.069	
52%	0.2					Pb.cert	4.081	
73%	0.23							
68%	0.27							
63%	0.3							
52%	0.33							
81%	0.37							
99%	0.4							
97%	0.44							
100%	0.47							
99%	0.5							
100%	0.54							
89%	0.57							
92%	0.61							
89%	0.64							
86%	0.67							
78%	0.71							
86%	0.74							
86%	0.78							
89%	0.81							
84%	0.84							
76%	0.88							
78%	0.91							
76%	0.94							
68%	0.98							
50%	1.01							
84%	1.05							
0%	1.22							
0%	1.25							
70%	1.28							
63%	1.32							
55%	1.35							
63%	1.39							
0%	1.42							
D.avg	66.5%	D.avg		D.avg				
L	1.42	L		L				
Pb.600	0.000	Pb.600		Pb.600				
Ratio Pslb	0.0	Ratio Pslb		Ratio Pslb				

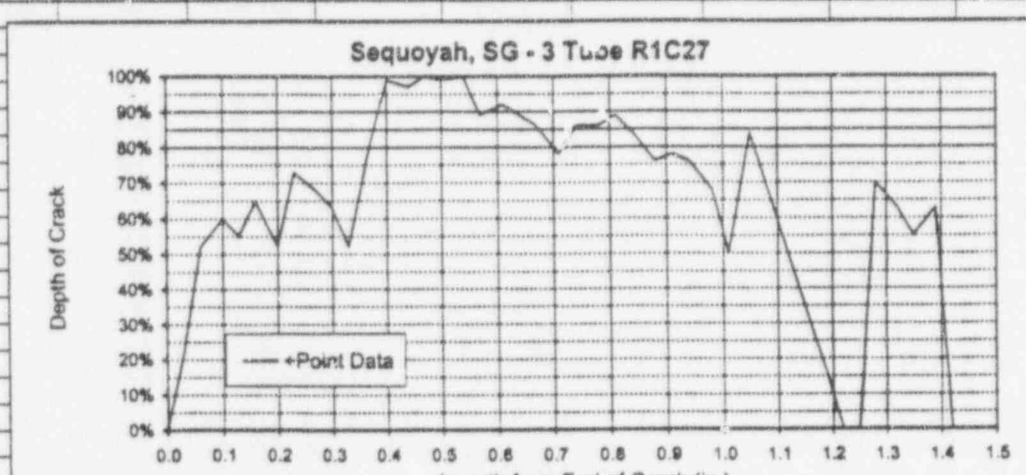


Table 4: Sequoyah 2, SG-3 ; Tube R1C38 U-bend Axial Crack; +Point Data

OD	t	Rm	Pfsbp			Sf.RT2OP	Sf.cert.	
0.875	0.050	0.4125	14326			0.9114	77.74	Op Temp
Pbar2Pb	P0	P.p	P.s	dP.op	dP.slb	Sf.str. hard	85.3	Rm Temp
0.000	0.000	2.250	0.831	1.419	2.560	91.14	Op Temp	
						100.00	Rm Temp	

+Point						+Point	
Crack Depths	Lengths	Crack Depths	Lengths	Crack Depths	Lengths	Weak Link Using BKHmodel	
0%	0.00					X.min	0.030
65%	0.03					X.max	0.750
76%	0.06					Length	0.720
73%	0.10					Depth	65%
70%	0.13					Pb / Sf	0.081
73%	0.17					Pb.str. hard	7.386
68%	0.20					Pb.cert	6.300
68%	0.23						
60%	0.27						
65%	0.30						
57%	0.34						
55%	0.37						
55%	0.37						
65%	0.41						
68%	0.44						
76%	0.47						
47%	0.51						
50%	0.54						
55%	0.58						
84%	0.61						
73%	0.64						
57%	0.68						
68%	0.71						
70%	0.75						
0%	0.78						
D.avg	62.9%	D.avg		D.avg			
L	0.78	L		L			
Pb.600	0.000	Pb.600		Pb.600			
Ratio Pslb	0.0	Ratio Pslb		Ratio Pslb			

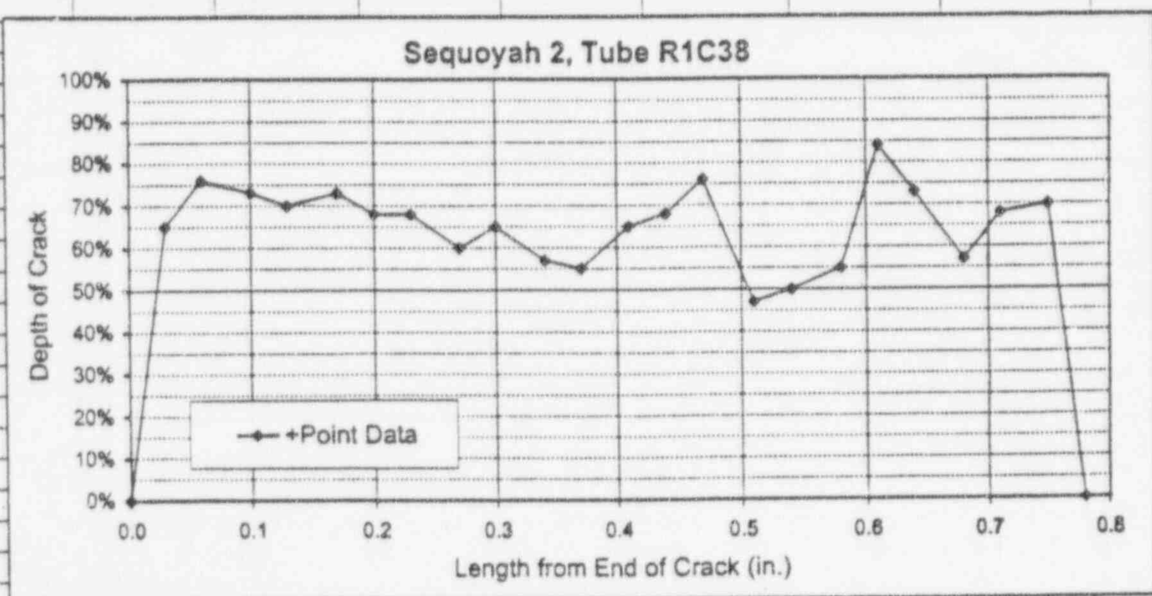
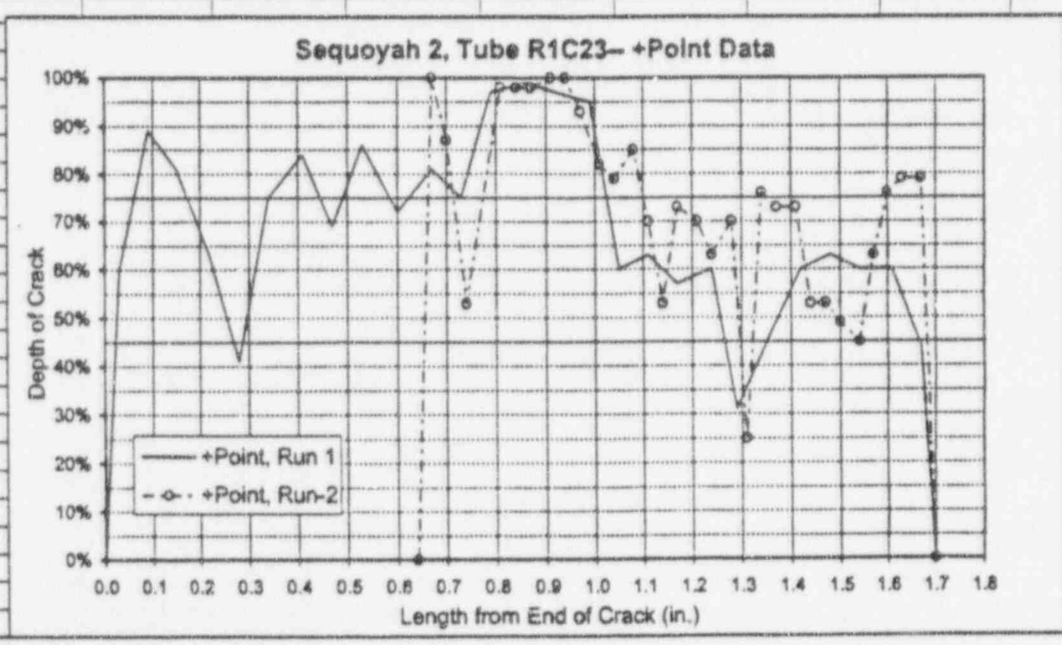


Table 5: Sequoyah-2, SG-4; Tube R1C23 U-bend Axial Crack; +Point Data

OD	t	Rm	Pfsbp			Sf.RT2OP	Sf.cert	
0.875	0.050	0.4125	14326			0.9114	76.38	Op Temp
Pbar2Pb	P0	P.p	P.s	dP.nop	dP.slb	Sf.str.hard	83.80	Rm Temp
0.000	0.000	2.250	0.831	1.419	2.560	91.14	Op Temp	
						100.00	Rm Temp	

+Point- Run 1		+Point Run 2				+Point Run 1	
Crack Depths	Lengths	Crack Depths	Lengths	Crack Depths	Lengths	Weak Link Using BKHmodel	
0%	0.00	0.0%	0.64			X.min	0.030
60%	0.03	100.0%	0.67			X.max	1.240
89%	0.09	87.0%	0.70			Length	1.210
81%	0.15	53.0%	0.74			Depth	76.2%
63%	0.220	98.0%	0.81			Pb / Sf	0.055
41%	0.28	98.0%	0.84			Pb.str. hard	5.043
75%	0.34	98.0%	0.87			Pb.cert	4.226
84%	0.41	100.0%	0.91				
69%	0.47	100.0%	0.94				
86%	0.53	93.0%	0.97				
72%	0.60	82.0%	1.01			+Point Run2	
81%	0.67	79.0%	1.04			Weak Link Using	
75%	0.73	85.0%	1.08			BKHmodel	
97%	0.79	70.0%	1.11			X.min	0.64
99%	0.86	53.0%	1.14			X.max	1.67
97%	0.92	73.0%	1.17			Length	1.03
95%	0.99	70.0%	1.21			Depth	72.9%
60%	1.05	63.0%	1.24			Pb / Sf	0.063
63%	1.11	70.0%	1.28			Pb.str.hard	5.747
57%	1.17	25.0%	1.31			Pb.cert	4.816
60%	1.24	76.0%	1.34				
31%	1.29	73.0%	1.37				
47%	1.36	73.0%	1.41				
60%	1.42	53.0%	1.44				
63%	1.48	53.0%	1.47				
60%	1.54	49.0%	1.50				
60%	1.61	45.0%	1.54				
44%	1.67	63.0%	1.57				
0%	1.70	76.0%	1.60				
		79.0%	1.63				
		79.0%	1.67				
		0.0%	1.70				
D.avg	68.7%	D.avg	44.9%	D.avg			
L	1.70	L	1.70	L			
Pb.600	0.000	Pb.600	0.000	Pb.600			
Ratio Pslb	0.0	Ratio Pslb	0.0	Ratio Pslb			



SEQUOYAH 05/06/96 INLET UNIT: 2 SG: 3 REEL: 3H69 RES

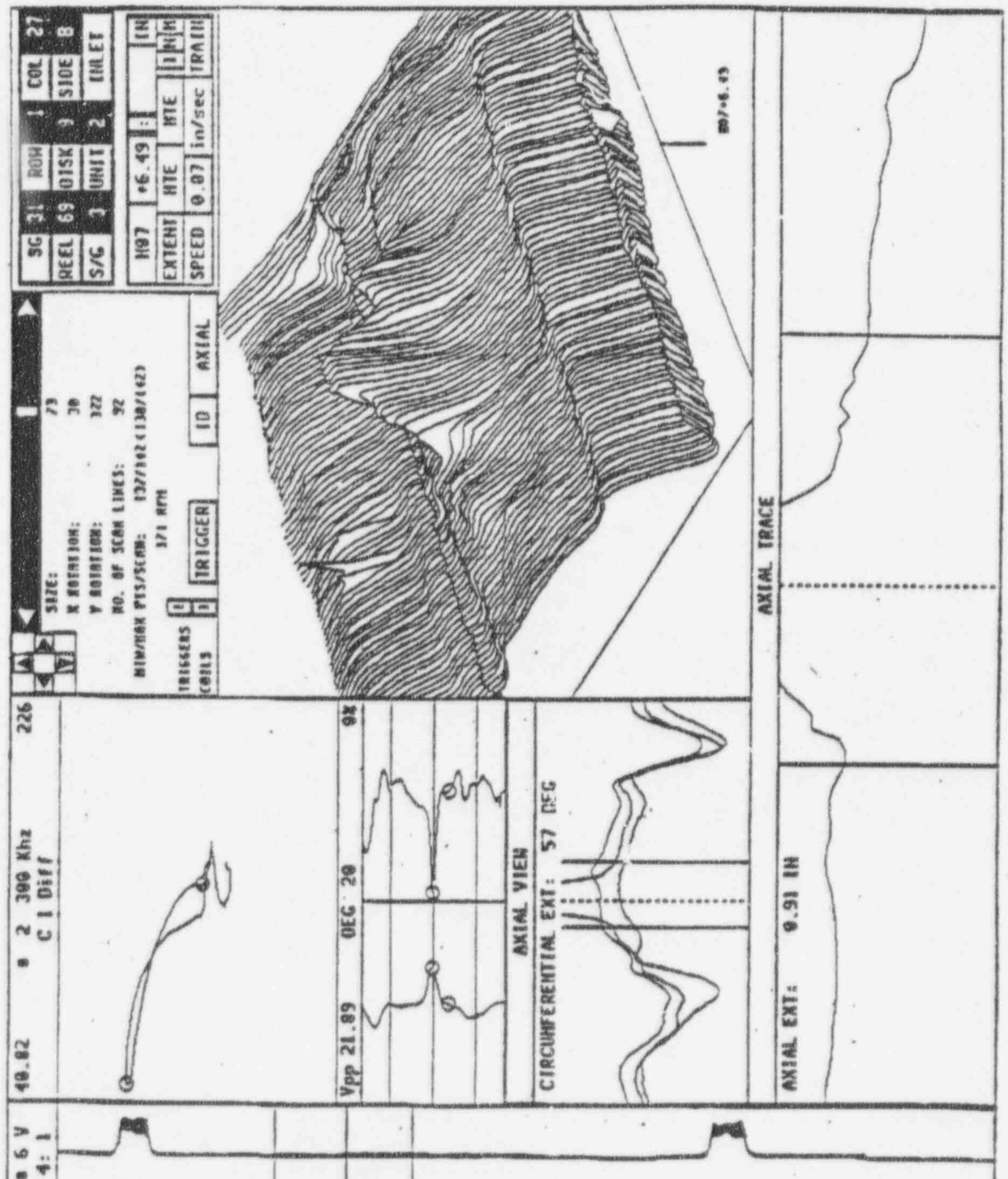


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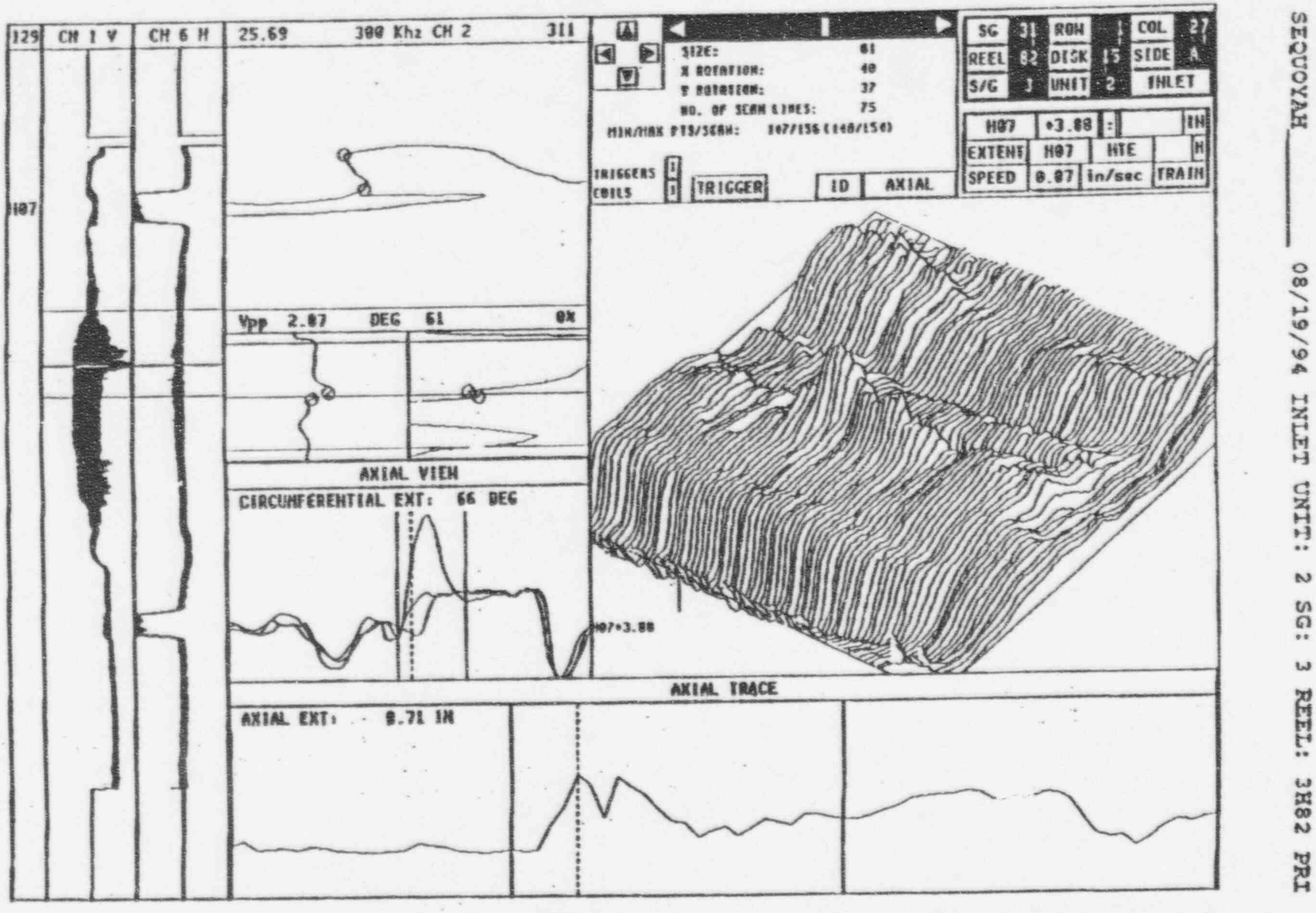
Figure 1. Tube R1C27 '96 Field Data, Pancake Coil U-Bend Indication

Figure 2. Tube R1C27 '94 Field Data, Pancake Coil U-Bend Indication



SEQUOYAH 05/11/96 INLET UNIT: 2 SG: 3 REEL: 3H93 RES

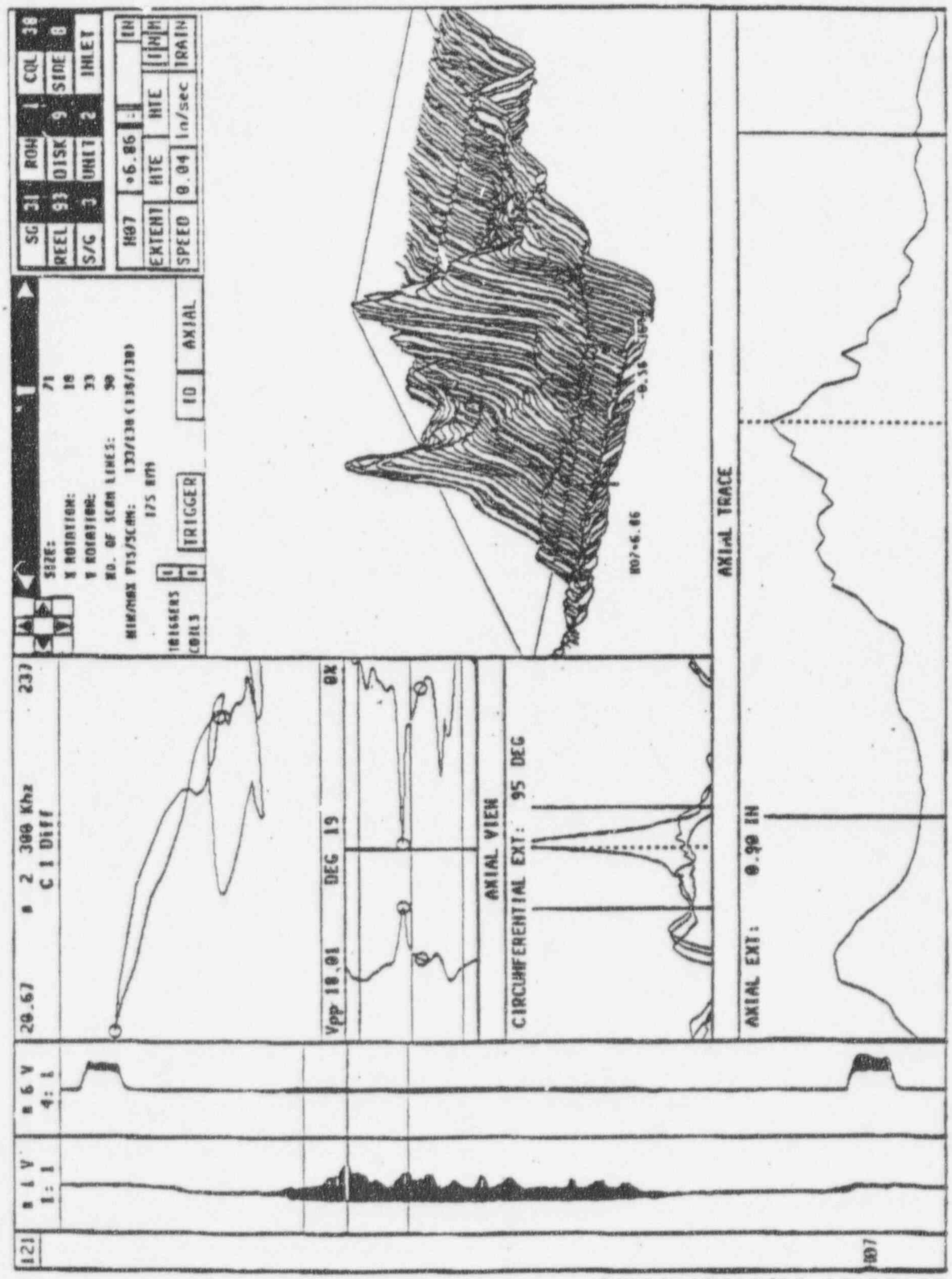


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Figure 3. Tube R1C38 '96 Field Data, Pancake Coil U-Bend Indication

Figure 4. Tube R1C38 '94 Field Data, Pancake Coil U-Bend Indication

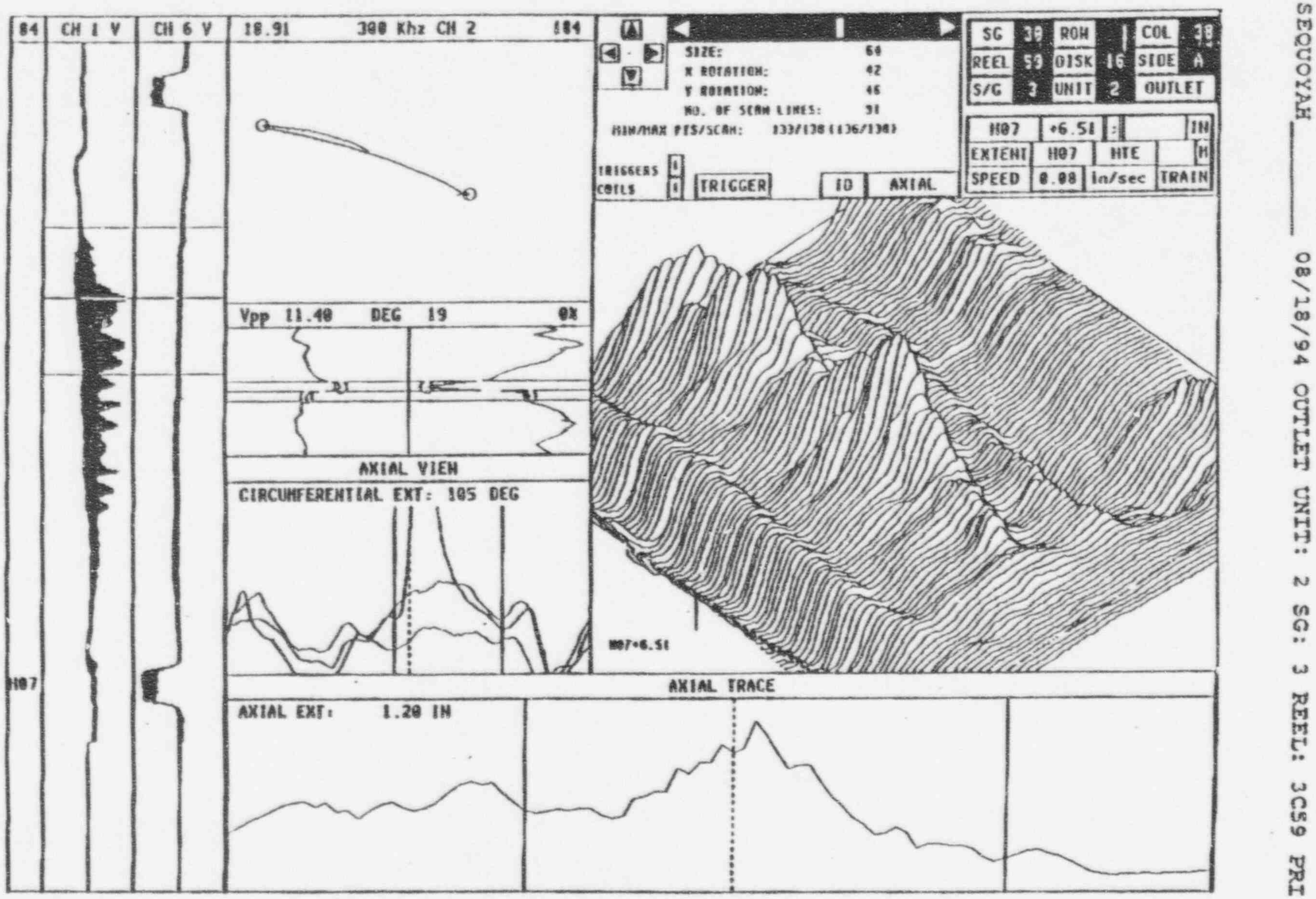
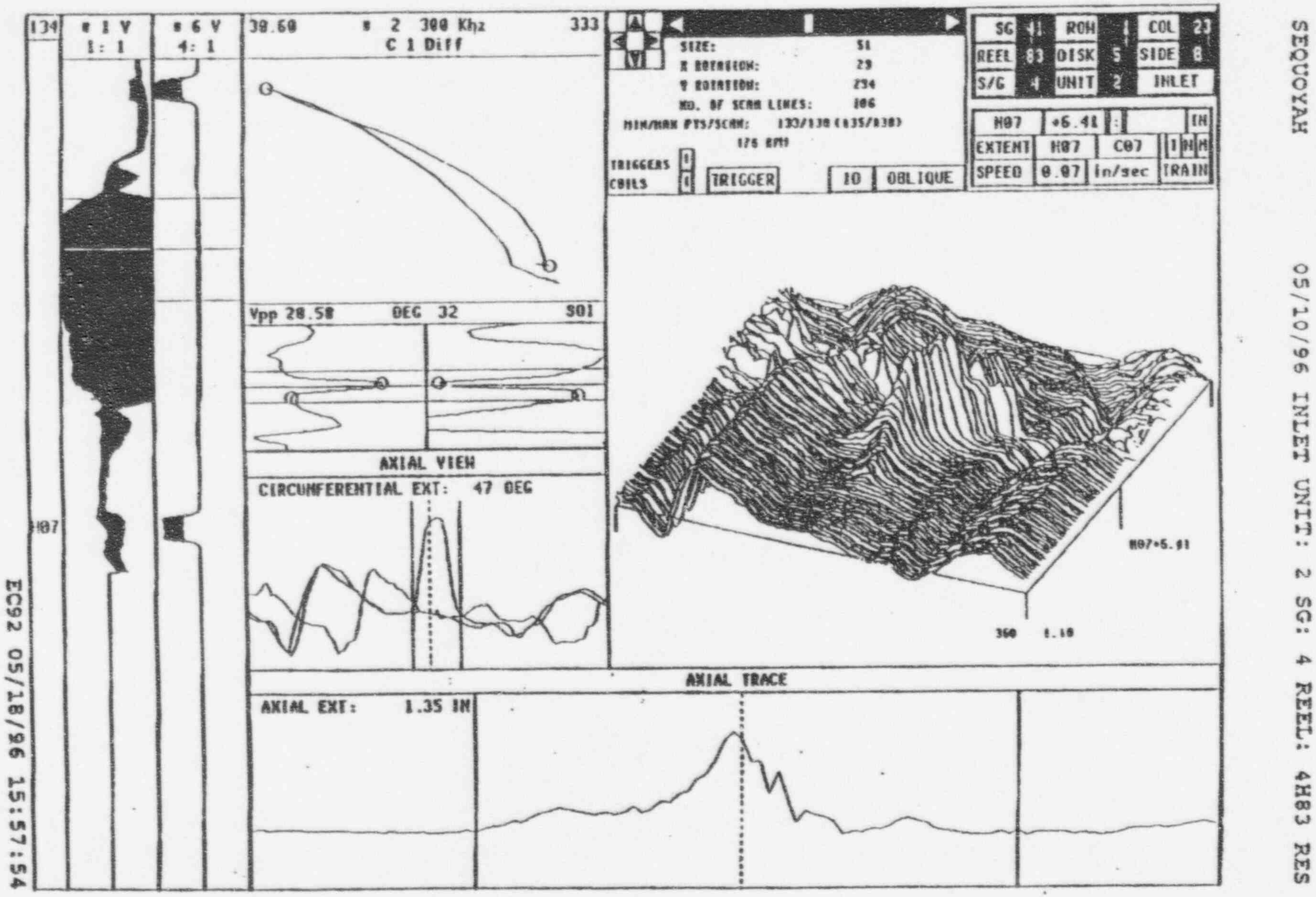


Figure 5. Tube R1C23 '96 Field Data, Pancake Coil U-Bend Indication



SEQUOYAH________ 08/17/94 INLET UNIT: 2 SG: 4 REEL: 4H74 SEC

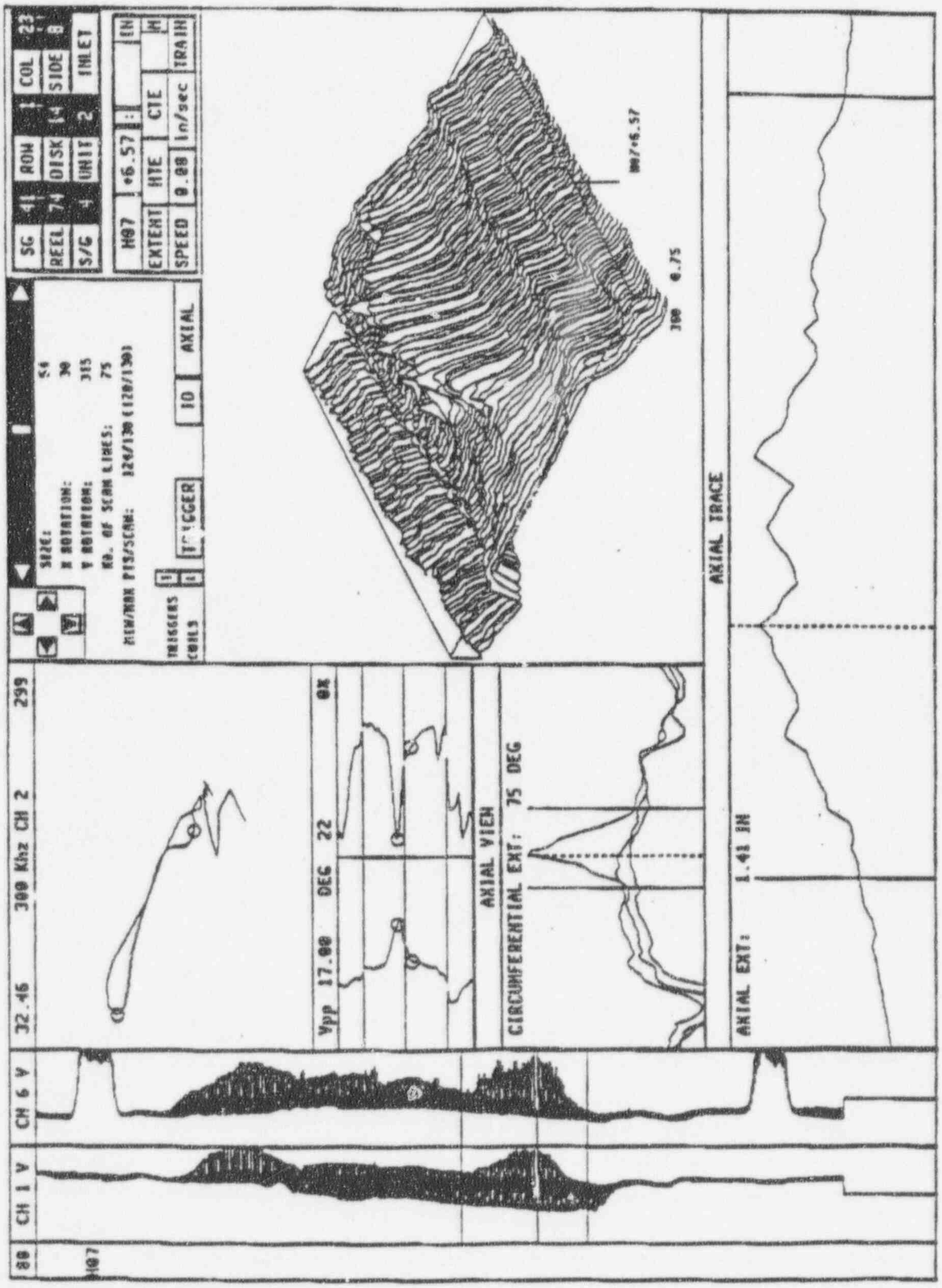


Figure 6. Tube R1C23 '94 Field Data, Pancake Coil U-Bend Indication

SEQUOYAH 05/11/96 INLET UNIT: 2 SG: 3 REEL: 3H93 DNT

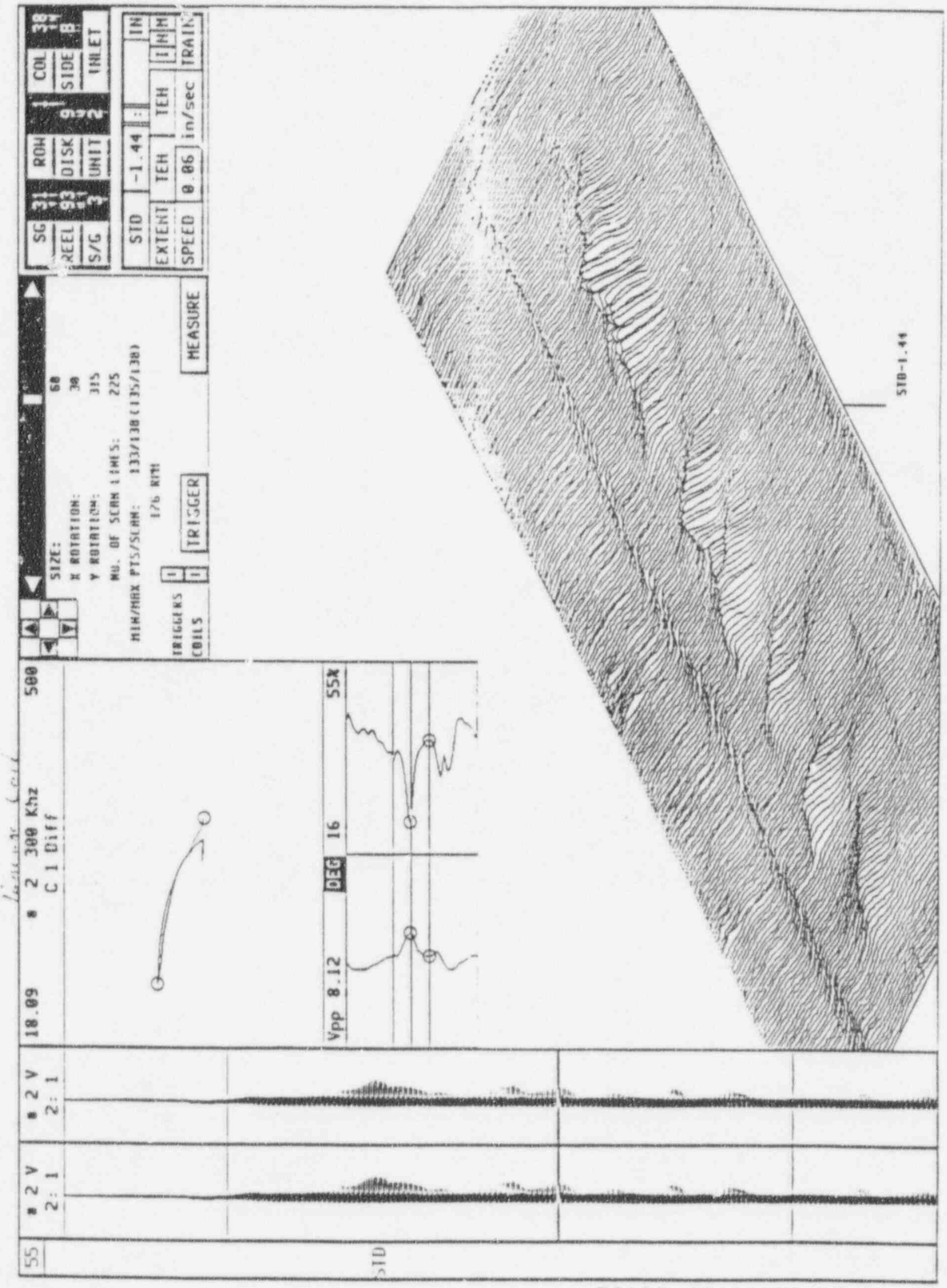


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Figure 7. Tube R1C38 '96 Data, Laboratory Analysis of Pancake Coil U-Bend Indication

SEQUOYAH 05/10/96 INLET UNIT: 2 SG: 4 REEL: 4H83 DNT

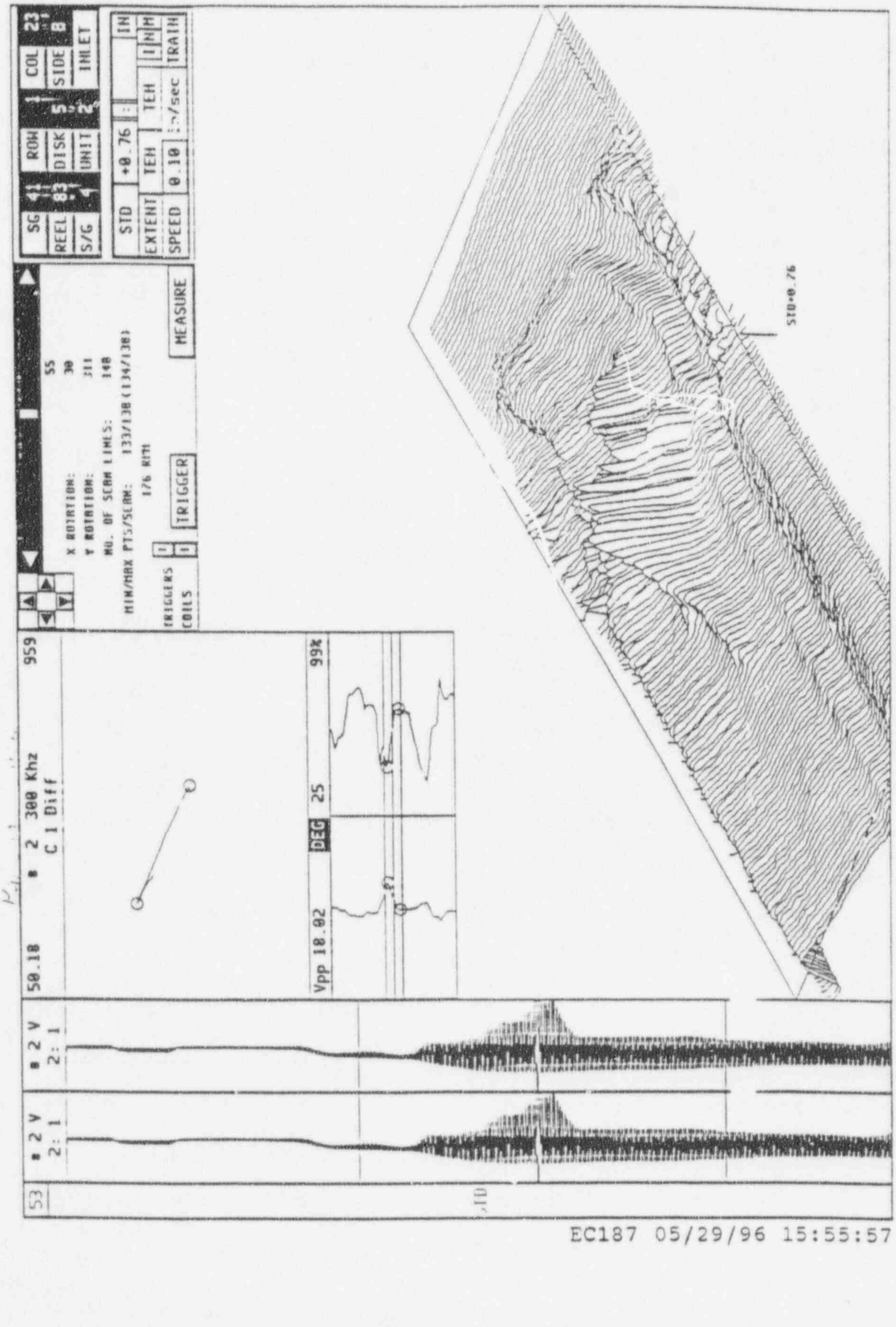

Figure 8. Tube R1C23 '96 Data, Laboratory Analysis of Pancake Coil U-Bend Indication

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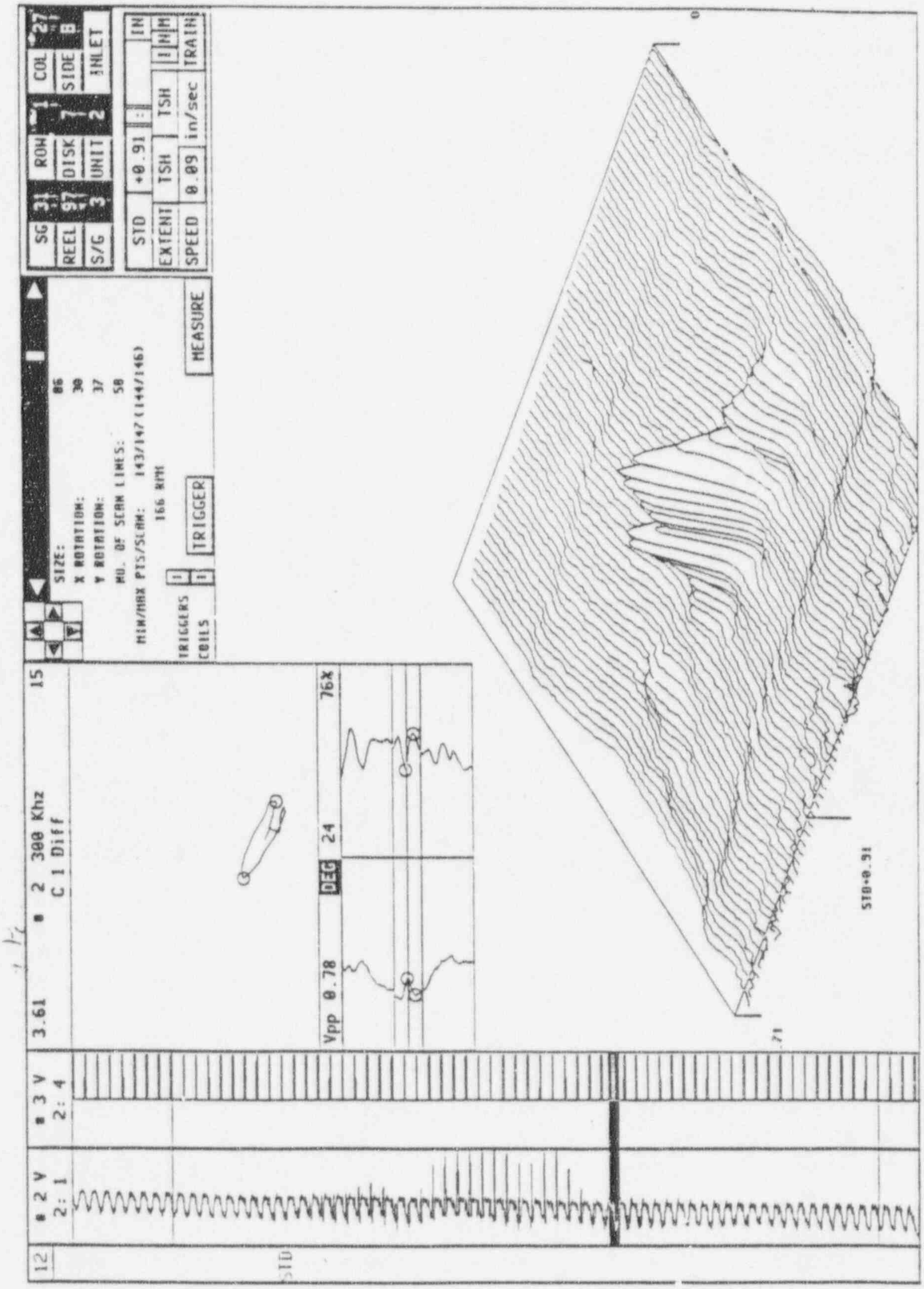
Figure 9. Tube R1C27 '96 Data, Laboratory Analysis of + Point Coil U-Bend Indication



SEQUOYAH 05/12/96 INLET UNIT: 2 SG: 3 REEL: 3H97 DNT

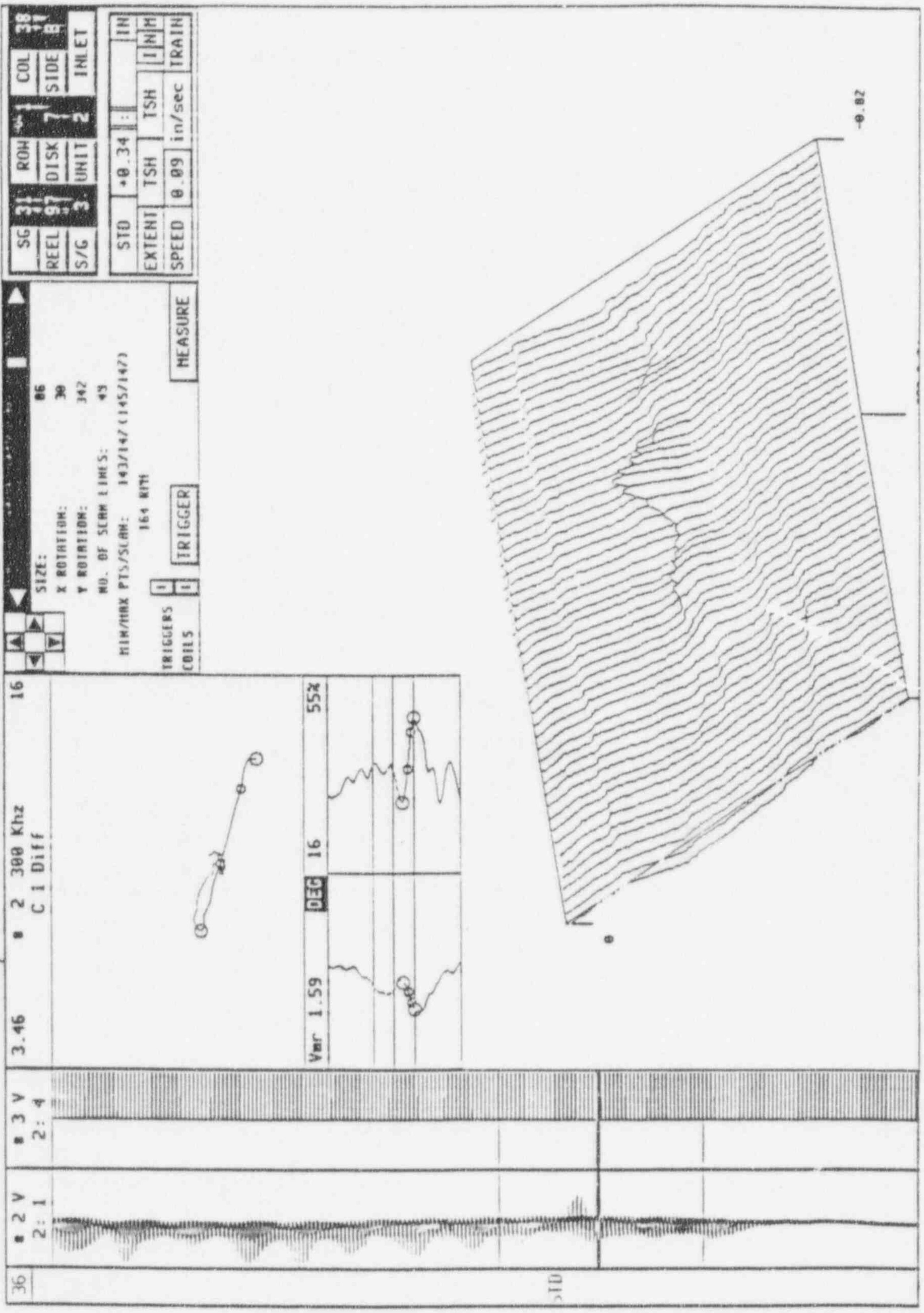


Figure 10. Tube R1C38 '96 Data, Laboratory Analysis of + Point Coil U-Bend Indication

EC187 05/29/96 13:44:39

SEQUOYAH 05/16/96 OUTLET UNIT: 2 SG: 4 REEL: 4C112 DNT

Figure 11. Tube R1C38 '96 Data, Laboratory Analysis of + Point Coil U-Bend Indication

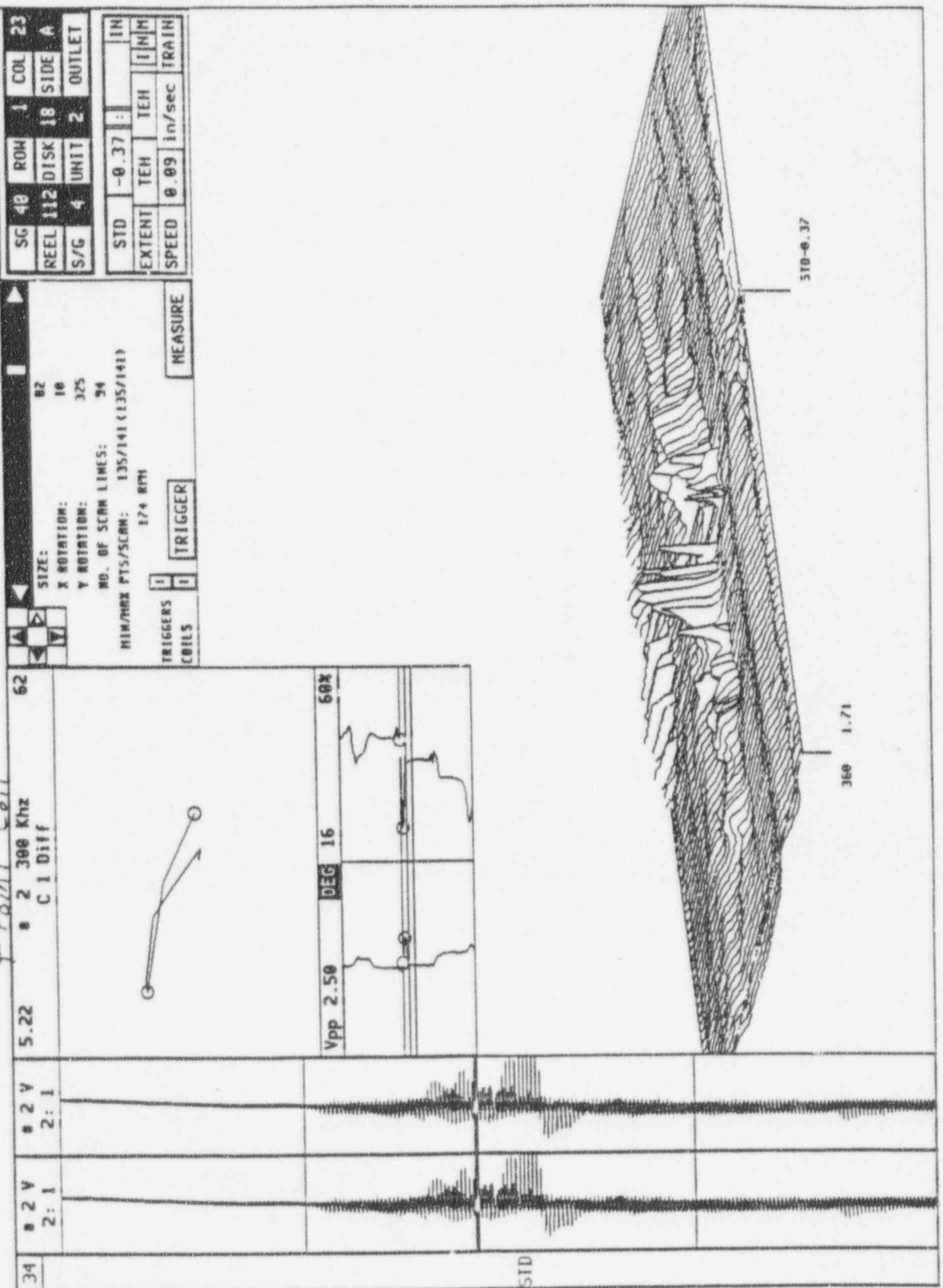


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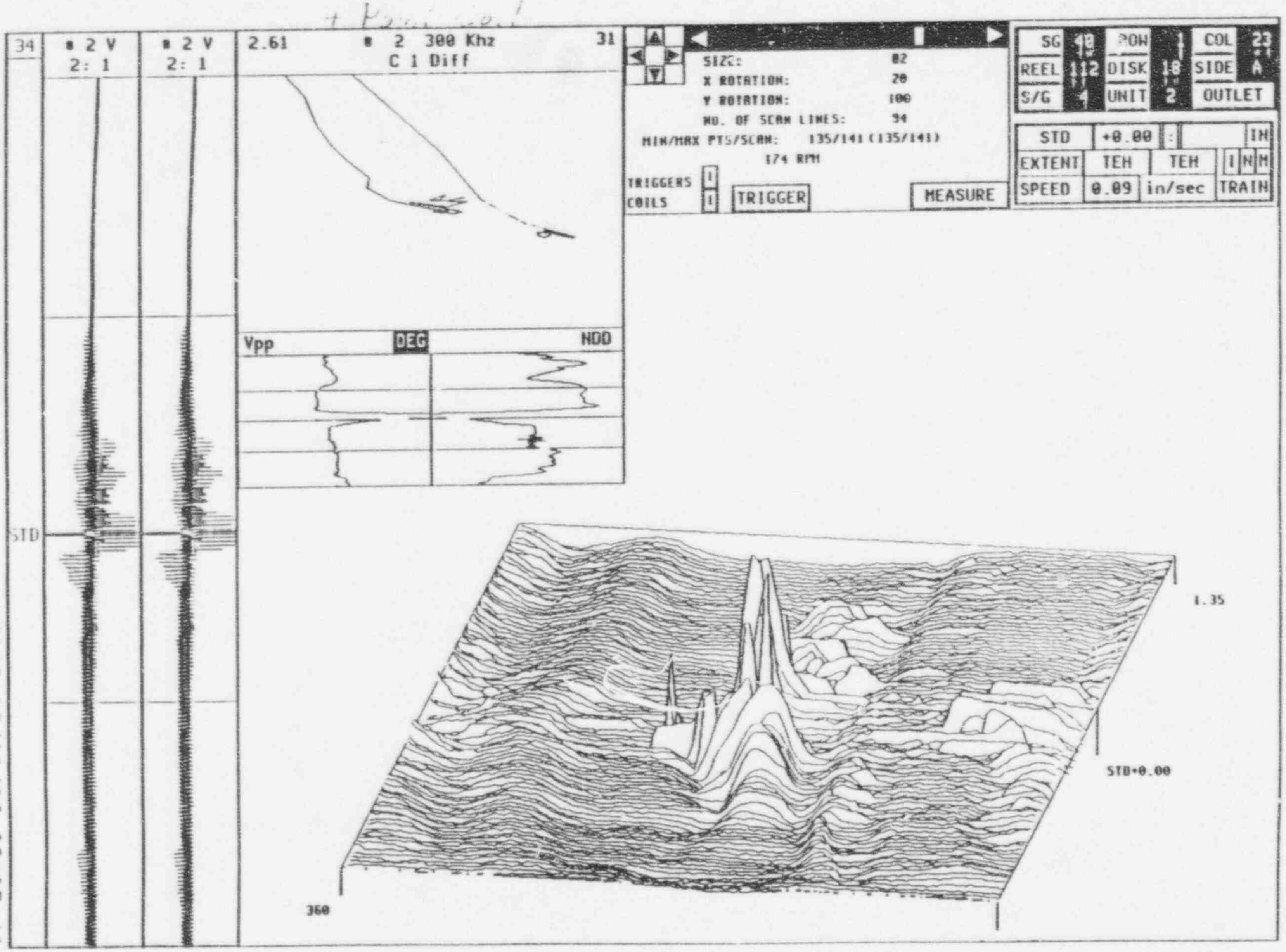
Figure 12. Tube R1C38 '96 Data, Laboratory Analysis of + Point Coil U-Bend Indication



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