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Subject: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
Additional Testing Results Supporting the ANO-2 Deterministic Operational Assessment of Steam Generator Tubing for the Remainder of Cycle 14

Gentlemen:

As discussed in our May 30, 2000 (2CAN05008), letter, additional testing using EDM notches has confirmed the conclusions of the deterministic operational assessment submitted on February 11, 2000 (2CAN020005). Attached is a summary description of the testing performed and results obtained to date. The additional testing performed since our May 30 letter provides further substantiation of our original conclusion that structural integrity of tube 72-72 surpassed the 3ΔP criterion during 2P99 and therefore, that Arkansas Nuclear One, Unit 2, can operate safely and in compliance with its operating license and Entergy's commitment to NEI 97-06 for the remainder of cycle 14.

Should you have any questions concerning this submittal, please contact me.

Very truly yours,

Jimmy D. Vandergrift
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JDV/jjd
attachment

A001

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EDM Test Sample Chronology for ANO-2

Objective:

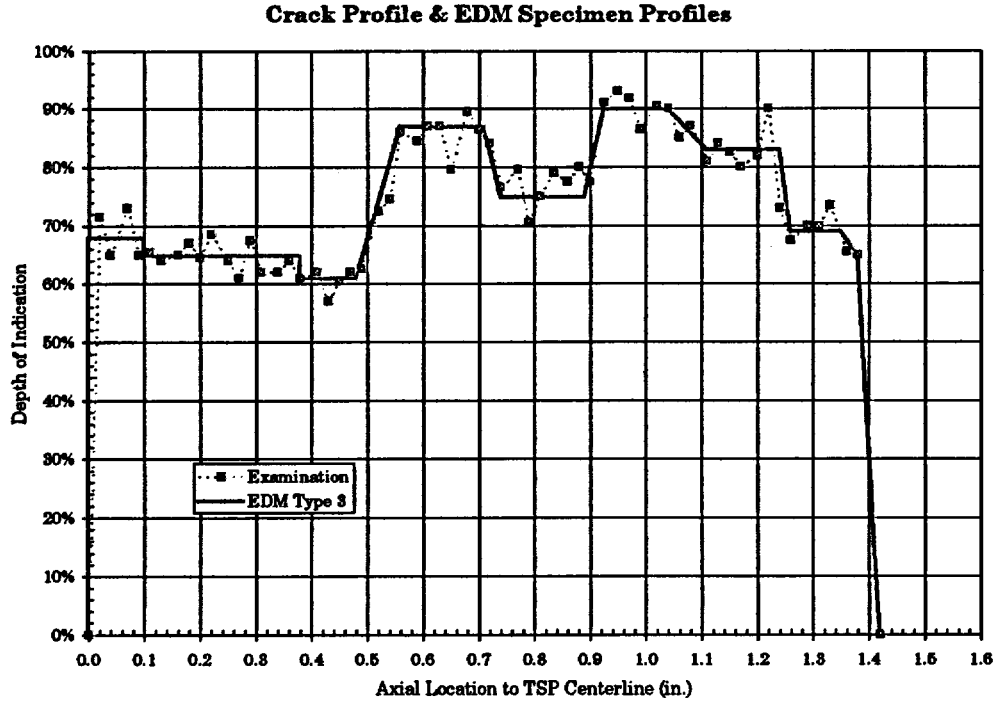
Develop electric discharge machine (EDM) notches that mimic tube 72-72 leakage profile.

Validate the operational assessment results ($\geq$ 500 psi delta between ligament tearing and burst).

Results:

Listed below is a summary of the EDM samples and corresponding test data that was developed to support the deterministic operational assessment (OA) developed following 2P99. The OA concluded that tube 72-72 met 3ΔP due to an additional 500 psi that would be gained from the point of ligament tearing to burst. This was based on using the Argonne National Laboratory (ANL) ligament tearing model and the Westinghouse burst model to determine ligament tearing and burst. The analysis was supplemented by previous EDM notches that were 0.5 and 0.7 inches in length. Based on concerns raised by the NRC Staff that the samples were not representative, additional EDM samples were fabricated and tested that were similar to the eddy current (EC) profile of tube 72-72. Listed below in Figure 1 is the EC profile of tube 72-72 and the initial EDM sample cut to replicate the tube 72-72 profile.

Figure 1



Different profiles were assigned a specific Type number. All specimens of the same type were machined to the same specification. The profile shown in Figure 1 was designed as a Type 3 EDM notch.

Six specimens (Type 3) were prepared and tested. Table 1 provides the test data:

Table 1

Specimen #	Type	Ligament Tearing psi	Leakage gpm	Peak Pressure psi	Burst
30	3	N/A	N/A	2487	N
31	3	N/A	N/A	2525	N
32	3	2980	0.0001	2992	N
33	3	2943	0.0055	3132	N
34	3	2122	0.0003	3086	N
35	3	2162	0.0002	3086	Y

The pressures listed have been corrected for material properties. The heat of material used on Type 3 notches had an average material property of (ultimate + yield of ~ 153 ksi) while the ANO-2 tubing for row 72 was 143 ksi. The remainder of the samples used a different lot that had a value of 155.8 ksi. These values result in a correction of 6.5 % for the Type 3s and 8.2 % for the remainder of the tubing.

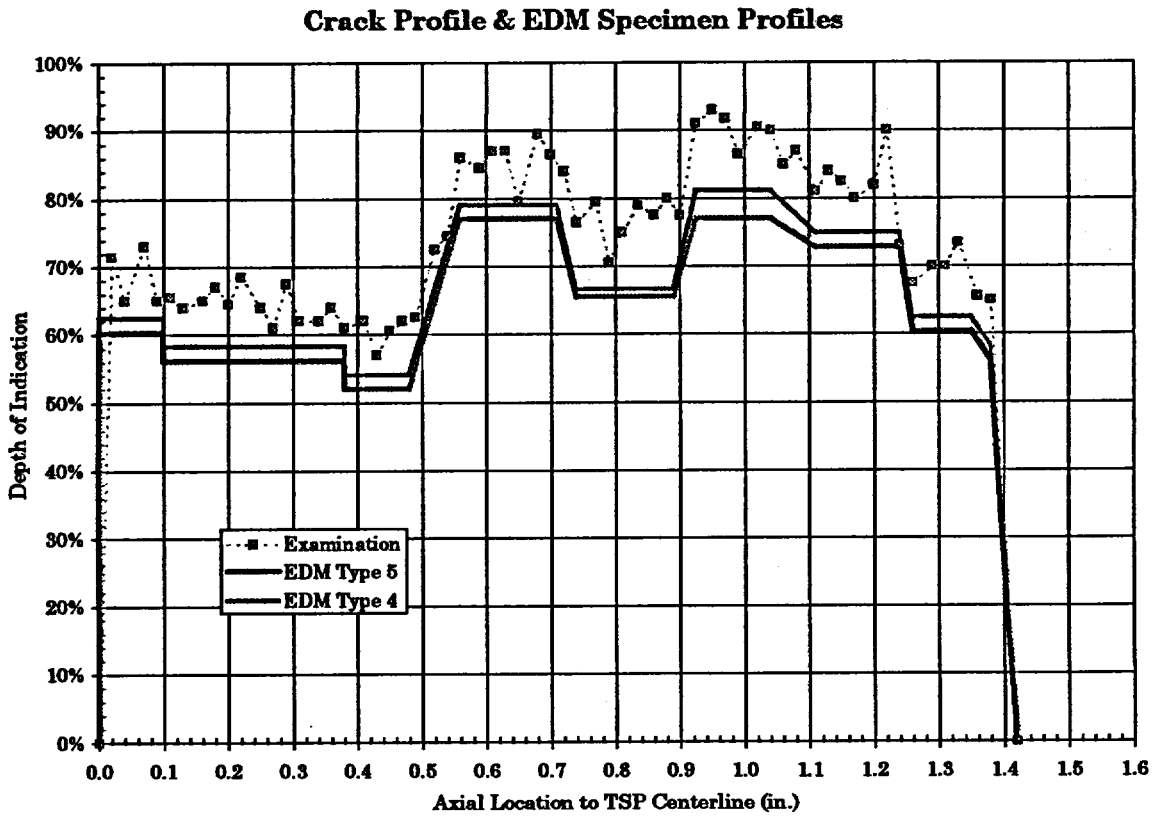
The first two samples (30 and 31) were taken to burst with a bladder. Their burst pressure was significantly lower than the ultimate pressure obtained during the in-situ pressure test of tube 72-72 and as much as 2000 psi below the predicted burst pressure. The remaining four samples were leak tested. Upon ligament tearing, the flaws opened over a one-inch length and wide enough such that the tube could not be re-pressurized.

During in-situ pressure testing, tube 72-72 began leaking at 3737 psi, well above design basis accident pressure, and ultimately reached a pressure of 4147 psi where ligament tearing occurred and leakage exceeded the capacity of the test device.

These results substantiate that the EC profile was overcalling the actual flaw average depth. This was not unexpected given a review of pulled tube data which was analyzed using a specific Examination Technique Specification Sheet (ETSS) developed by Westinghouse. This data indicated that EC was overcalling the depth by approximately ~

4%. An evaluation of the flaw profile was performed utilizing the ligament tearing model. This evaluation determined that if the same profile was reduced by ~ 8 % overall, the pressures would correlate with tube 72-72. The next series of samples were produced by reducing the flaw profile in overall depth by 7 % and 10 % to bound the estimated size and are labeled as Types 4 and 5 respectively. Figure 2 is a graphic representation of these notches along with the original EC profile of tube 72-72.

Figure 2



These revised profiles result in higher ligament tearing pressure, but the length of the flaw opening upon ligament tearing prevented the tube from being burst tested (bladder extruded). The length of the flaw opening was approximately 1.0 inch and had excessive leakage such that it could be re-pressurized to only 50 psi with the test equipment.

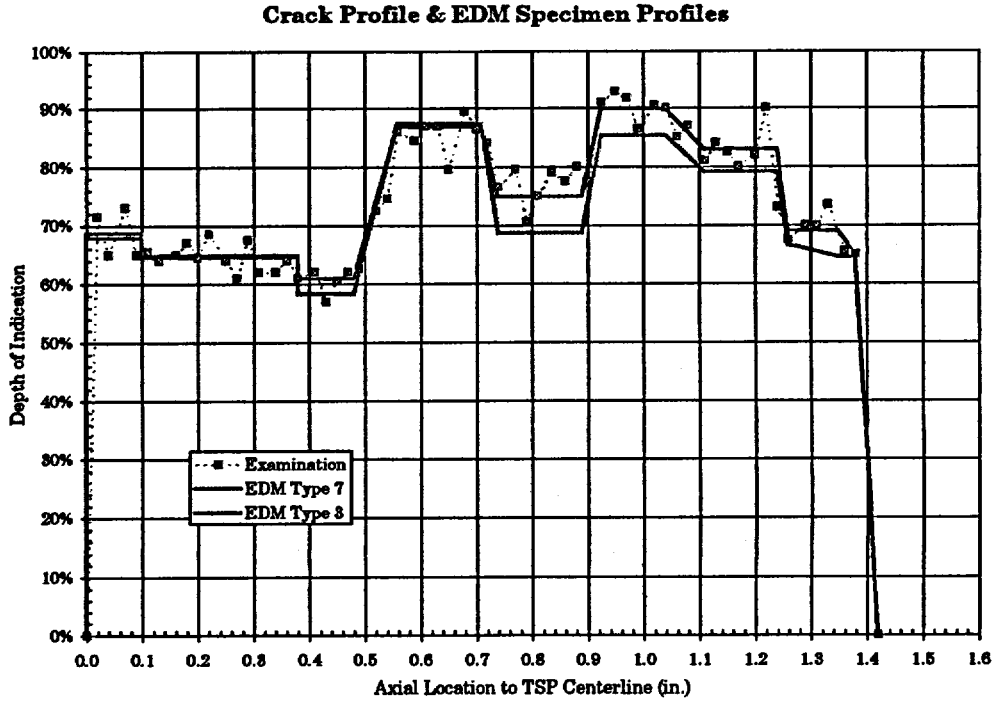
Table 2

Specimen #	Type	Ligament Failure psi	Length in	Bladder Pressure psi	Tearing	Leakage gpm*	Pressure* psi
50	4	4552	1	2497	N	2.37	35
54	4	3947	1.01	2487	N	2.4	40
55	4	4589	0.9	2561	N	2.3	40
57	4	4314	0.94	2322	Y	2.4	40
51	5	4093	0.875	2405	Y	2.5	30
52	5	4002	1	2194	Y	2.3	30

* Post Ligament Tearing

These results next led to a modification of the profile to better mimic the leakage profile from the in-situ pressure test of tube 72-72. Tube 72-72 had 3 significant changes in flow rates due to ligament tearing. Types 3-5 tore instantly with no leakage prior to opening of the flaw. Type 7 flaws were developed with the profile shown in Figure 3:

Figure 3



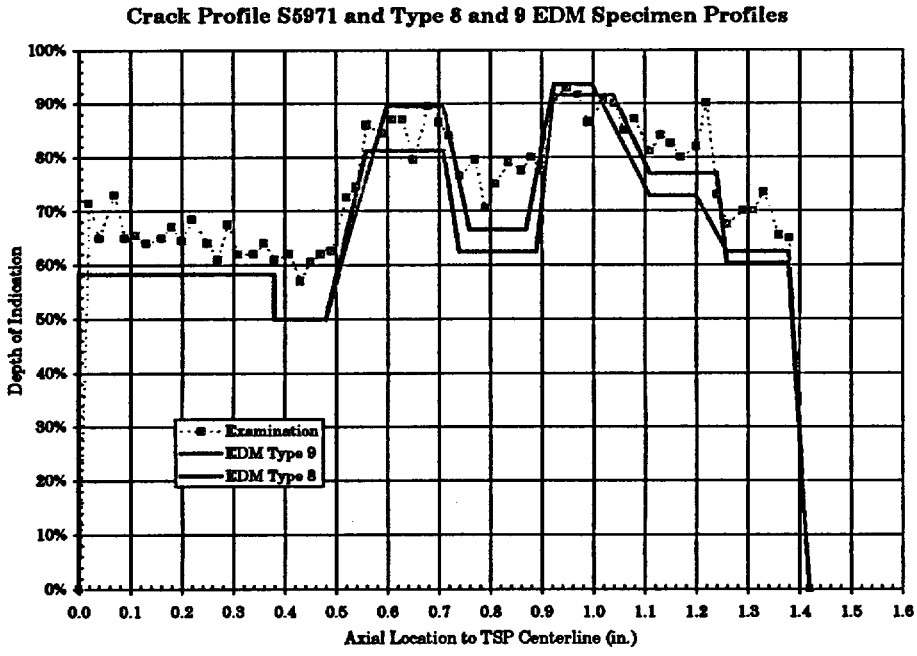
The difference in this flaw and the original Type 3 flaw is the reduced peak to decrease the pressure of ligament failure and increased the ligament between the two peak depths to control the length of the opening. It is likely the ligament between the two peaks shown on the eddy current profile is deeper due to eddy current look ahead effect. Listed below in Table 3 are the results from the Type 7 flaw testing:

Table 3

Specimen #	Type	Ligament Tearing psi	Length in	Burst	Leakage gpm	Pressure psi
49	7	3442	0.937	N	2.3	40
59	7	3543	0.75	N	2.3	40
53	7	3056	0.75	N	2.4	70

The Type 7 profiles showed reduced ligament tearing pressure. The post ligament tear response was not correct (the leakage-profile, while better, was still significantly different from tube 72-72) because the flaws opened their entire length without significant prior leakage. This led to the creation of Type 8 and 9 notches. Their profiles are shown in Figure 4:

Figure 4



The Type 8 and 9 notches improved the leakage profile and the initial ligament failure pressure. The length of the flaw openings (post-test) were still ~ 0.85 inch. This resulted in a greater leakage rate than what tube 72-72 experienced. However, the flaw did experience separate ligament pop-throughs at increasing pressures. Listed below is a table of results for Type 8 and 9 notches:

Table 4

Specimen #	Type	Ligament Tearing psi	Length in	Bladder Pressure psi	Burst	Leakage gpm	Pressure psi
60	8	3167	0.870	2552	Y	0.86	3167
61	8	2203	Mist	3763	N	0.49	2891
62	8	-	-	4094	Y	-	-
63	9	2937	0.86	3029	N	>.27	3121
64	9	3139	-	3580	N	0.56	3121
65	9	-	-	4158	N	-	-

With these test specimens, the pressures were still considerably lower than 72-72, but the leakage profile was better. Type 12 and 14 were developed next. These notches were the same profile as the Type 9 flaw but with a slightly deeper ligament, while the axial lengths of the two peaks were decreased slightly to result in a shorter opening of the flaw. The Type 12 ligament depth was 63 % through-wall (TW) and Type 14 was 56 %TW as compared to the Type 9 with a 67 % TW ligament. This is displayed in Figure 5 below:

Figure 5

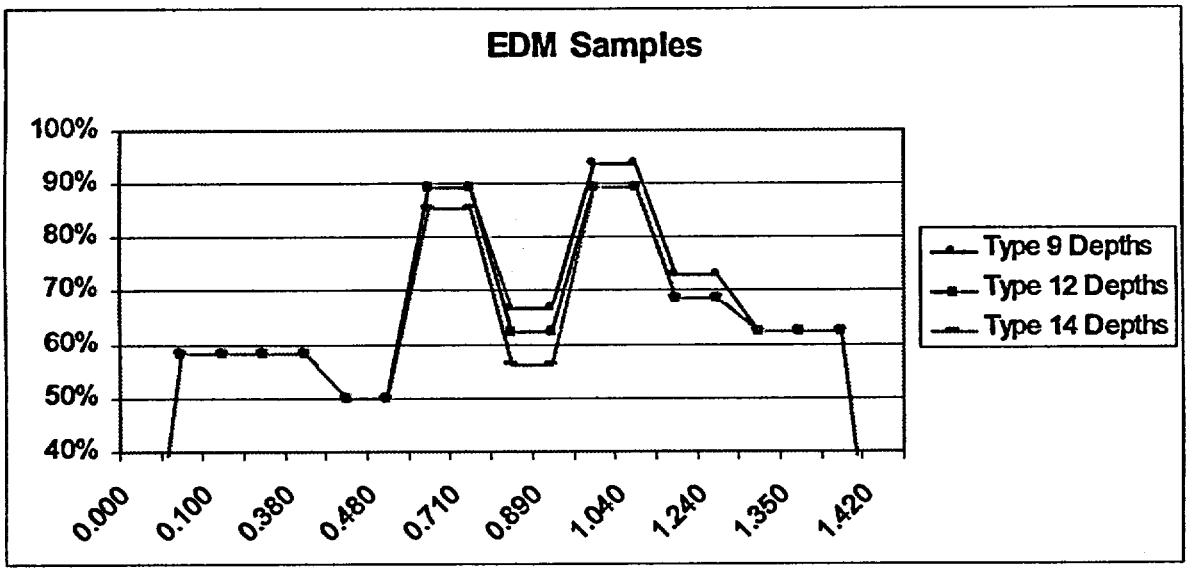


Figure 5 is enlarged so the details of the ligament and peak depths can be better assessed. Table 5 listed below is a summary of the data taken from the leakage and burst tests:

Table 5

Specimen #	Type	Ligament Tearing psi	Length in	Bladder Pressure psi	Burst	Leakage gpm	Pressure psi
71	12	4222	1.42	3616	Y	0.77	3304
72	12	3488	0.757	2735	Y	0.009 0.04	3396 3442
73	12	-	1.42	4222	Y	-	-
66	14	4010	0.75	NA	N	0.0125 0.45 9.3	4010 3947 100
67	14	4350	0.75	NA	N	0.1 0.52 0.96	4350 4222 3763
68	14	3396	NA	2965	Y	0.5 1.13 3.2	3093 3396 826
69	14	3350	0.692	2680	Y	0.27	3350
70	14	-	1.415	3965	N	-	-

The type 14 notches were the most similar to tube 72-72 based on the way the flaw behaved under various pressures, the associated flow rates and relative pressure at burst. Additional Type 14 notches were fabricated. Specimen 67 and the previous Specimen 68 exhibited very similar characteristics to tube 72-72. This comparison is listed below:

Table 6

	Start of Leakage	0.5 gpm Leakage	Ligament Failure
Specimen 67	4345	4222	4222
Specimen 68	2983	3093	_
Tube 72-72	3737	3573	4147

The following is a summary of the remaining Type 14 samples:

Table 7

Specimen #	Type	Ligament Failure psi	Length in	Bladder Pressure psi	Tearing	Leakage gpm	Pressure psi
74	14	3855	0.8	-	-	0.01	3855
						0.2	3946
							3956
						2.4	30
75	14	N/A	-	5231	Y	N/A	-
76	14	3488	0.8	-	-	0.59	3488
						0.61	3763
							4130
						2.4	30
77	14	N/A	-	5140	Y	N/A	-
83	14	3442	0.7	-	-	0.001	3212
						0.09	3350
						0.18	3368
						0.45	3423
						-	3442
						2.4	37

Table 7 (cont)

Specimen #	Type	Ligament Failure psi	Length in	Bladder Pressure psi	Tearing	Leakage gpm	Pressure psi
84	14	3488	0.6			0.001	3221
						0.16	3405
						0.24	3423
						0.48	3478
						1.1	3488
						1.42	3121
						2.4	184
85	14	3690	0.5	3121	Y	0.01	3616
						0.07	3644
						0.2	3662
						0.31	3671
						0.42	3680
						0.52	3690
						0.85	3534
						1.3	3121
						1.57	3029
						1.78	2845
						0.27	37
						0.75	298
						1	542
						1.25	789
						1.5	1055
						2	1450
						2.3	1579
86	14	-	NA	NA	NA	0.003	1836
						0.046	2203
						0.06	2249
						0.087	2295
						0.2	2478
						0.3	2616
87	14	-	-	4791	Y	-	-
88	14	-	-	4654	Y	-	-
93	14	-	-	4865	Y	-	-

Table 7 (cont)

Specimen #	Type	Ligament Failure psi	Length in	Bladder Pressure psi	Tearing	Leakage gpm	Pressure psi
94	14	-	-	4865	Y	-	-
95	14	-	-	4571	Y	-	-
96	14	-	-	5011	Y	-	-

Specimens 66 and 67 were tested with the Framatome Technologies Incorporated equipment and the remaining samples were tested with the Westinghouse equipment. Similar results were reported by both vendors. Specimens 75, 77, 87, 88 and 93-96 were taken to burst with a bladder while the remainder of the samples were tested to get leakage data. The following results were used to determine the pressure difference between ligament tearing and burst:

Table 8

Ligament Tearing

Specimen #	Pressure
66	4010
67	4350
68	3396
69	3350
74	3855
76	3488
83	3442
84	3488
85	3690

Average Value of 3674

Table 9

Burst Pressure

Specimen #	**Pressure**
75	5231
77	5140
87	4791
88	4654
93	4865
94	4865
95	4571
96	5011

Average Value of 4891

Delta =1217 psi

The 500 psi delta value assumed is well below the average delta obtained from the Type 14 specimens.

To further evaluate the consistency between tube 72-72 and the Type 14 notches, EC terrain maps were compared using the 0.115 pancake on 300 kHz. Figure 6 is the EDM Specimen 67 and Figure 7 is tube 72-72 pre in-situ test.

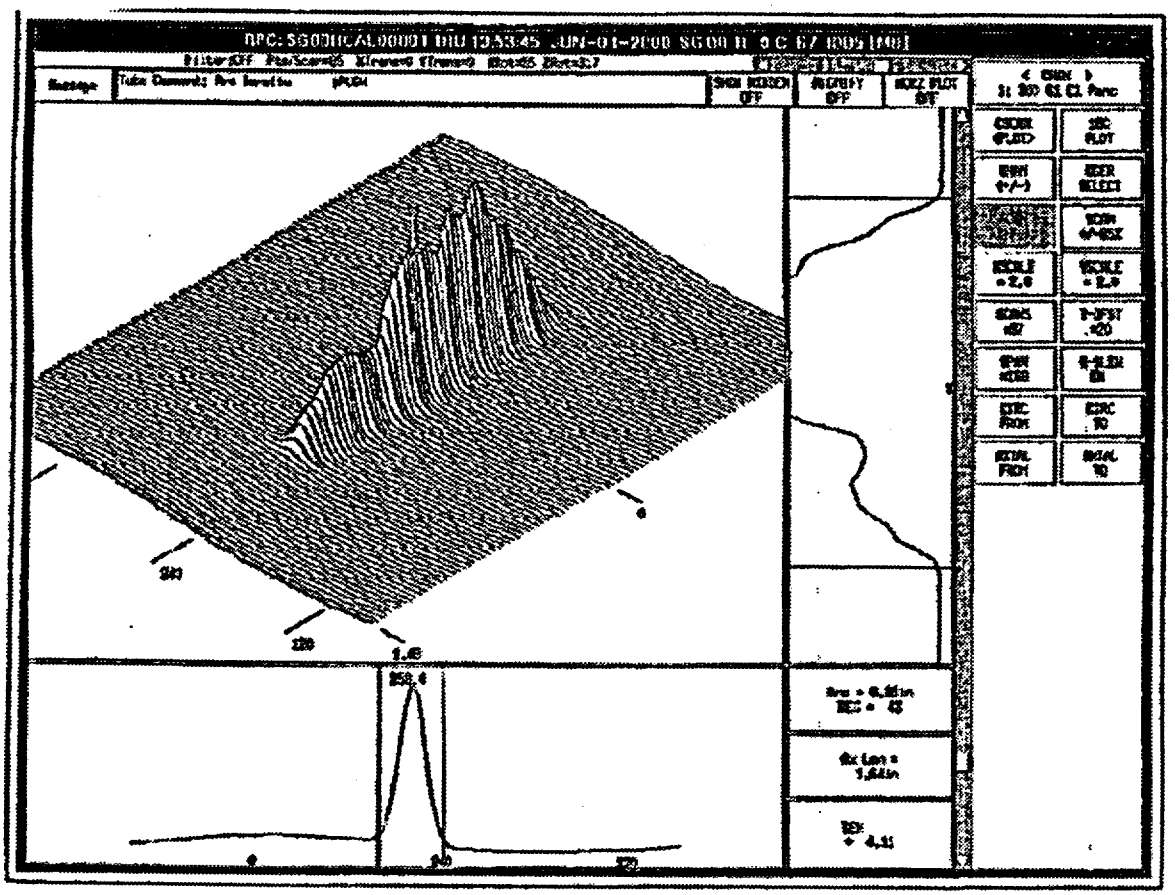


Figure 6

Eddy Current Terrain Map of EDM # 67

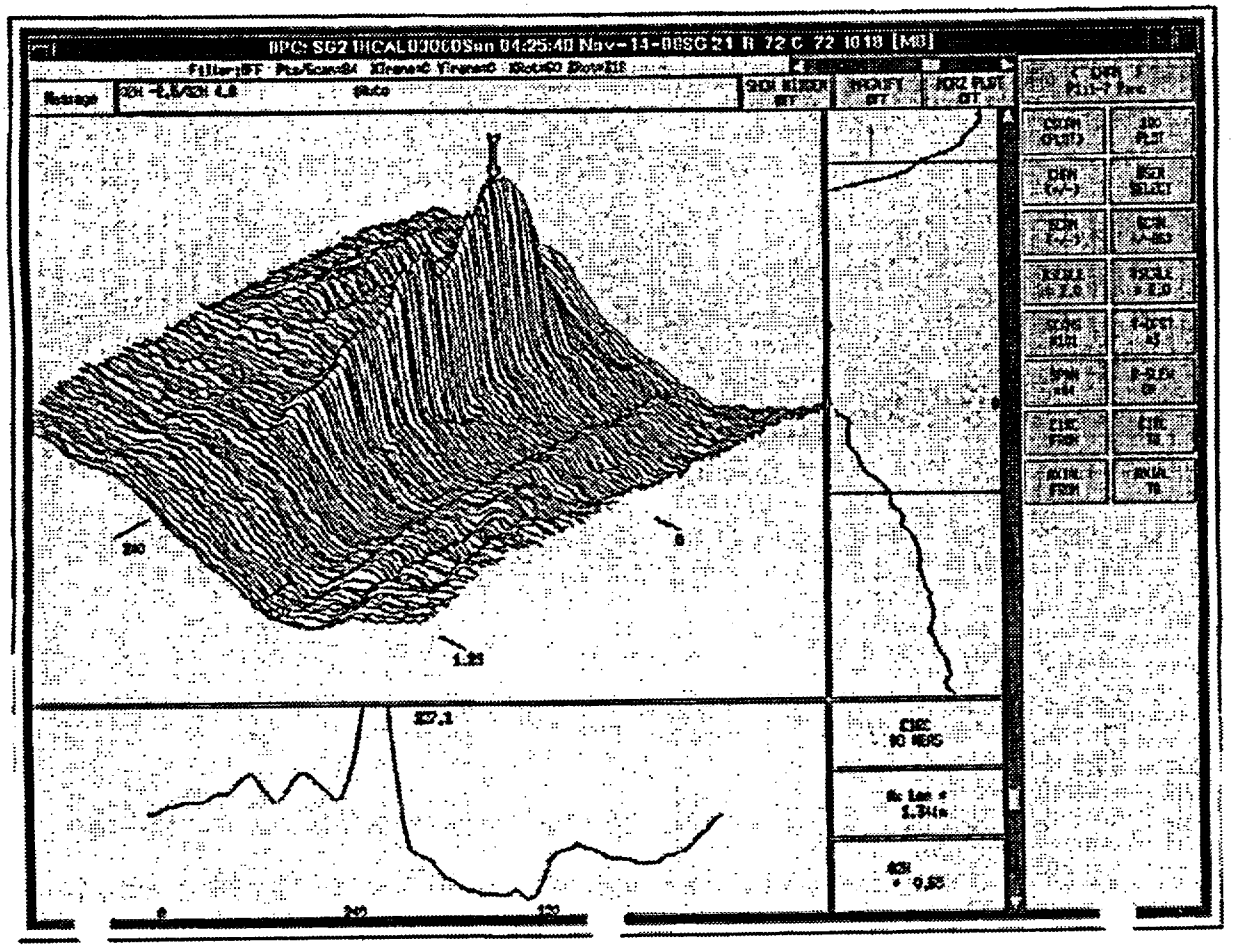


Figure 7

Eddy Current Terrain Map of Tube 72-72

Summary:

1.0 The EDM sample that matched the eddy current profile of tube 72-72 produced results that were significantly lower than both the leakage and ligament tearing of tube 72-72. The conclusion was that the EC profile was overly conservative on the depth calls. This was also supported by pulled tube information.

2.0 The Type 14 flaws matched the leakage profile of tube 72-72. When the delta is calculated from ligament tearing to burst, the value is greater than the original estimate of 500 psi.

3.0 Based on this supporting evidence, tube 72-72 was capable of achieving 3 ΔP with a 500 psi margin.