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ISSUE SUMMARY

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE FORT ST VRAIN REGION 25

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NEXT INDENTURED DOCUMENTS

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1. INTRODUCTION

This report describes the postirradiation examination (PIE) results obtained from the PGX graphite surveillance test element removed from FSV reactor region 25. Five test elements containing PGX graphite surveillance specimens were inserted into the bottom reflector region of the FSV reactor at the first refueling [Refs. 1,2]. The PGX surveillance program was funded by PSC to obtain data from the FSV reactor operation on the state of oxidation of PGX graphite in the reactor. By comparison between surveillance specimen performance and predictive computer codes the actual condition of the PGX core support blocks may be calculated. The retrievable test elements exposed PGX surveillance specimens to reactor conditions which were nearly the same as experienced by the PGX graphite core support blocks in the reactor. The extent of graphite oxidation in the surveillance specimens is assessed by periodic removal of test elements and examination of their PGX specimens. Comparison of the measured oxidation to the predicted oxidation of the surveillance specimens provided a basis for assessing the oxidation of the core support blocks using the same predictive methods.

Test element R-90-1 was removed from region 25 after approximately 2 calendar years in service. The test element contained 8 PGX surveillance specimens from billet 6484-112 and 8 specimens from billet 6484-138. The PIE of the 16 PGX surveillance specimens is the subject of this report.

2. TEST ELEMENTS

2.1 Materials

Each test element contained 16 PGX surveillance specimens taken from two billets of PGX graphite. The properties of comparison PGX specimens taken from the same locations in the same billets were reported earlier [2]. The PGX surveillance specimens were designed to be inserted into the machined reflector elements at eight coolant hole locations in each element as shown in Figure 1. Into each coolant hole location were inserted one H-327 graphite spacer, two PGX surveillance specimens, and one H-327 graphite cap as illustrated in Figure 2.

One PGX specimen from each parent PGX billet was placed in each of the 8 holes. The position of the PGX specimens was varied every 2 holes so that billet 6484-138 specimens were uppermost in the block in holes I, II, V, VI and specimens from billet 6484-112 were uppermost in the other four holes. The specimen loading record is presented as Figure 3. Initial weights and measurements of the surveillance specimens are given in Table 1.

Laboratory oxidation tests which were performed on companion PGX specimens were summarized by Figure 4 taken from Reference 2.

2.2 Reactor Service

The test element was positioned in column 7 of region 25 of the FSV reactor (Figure 5) during June 1979. The region 25 test element was removed from the reactor in May 1981. Temperature, power and moisture levels in the reactor were obtained from the FSV plant data logger system for the time period of interest.

3. PREDICTIONS OF OXIDATION

The CSBBO-3 computer code was used to predict the oxidation in the PGX surveillance specimens based upon actual reactor performance data obtained from the data logger. The predicted oxidation of the PGX specimens was reported elsewhere [3]. Predictions of PGX oxidation were based upon the PGX oxidation rate shown as a solid line in Figure 4, which is 1000 times the H-451 graphite oxidation rate. Since only one PGX oxidation rate was assumed, the predicted oxidation varied only with temperature and moisture level, with no differentiation between the 2 PGX billets.

Consequently, the predicted oxidation was constant between specimens in the same coolant hole, but varied between coolant holes. Dunn [3] predicted the overall weight loss for each specimen and also the burnoff profile or density gradient in each PGX specimen. The detailed predictions of Dunn [3] provided an excellent basis for comparison to actual measurements of oxidation.

4. PROCEDURES

4.1 Specimen Removal

The PIE of region 25 PGX surveillance specimens was performed following the published specifications [4]. The test element was placed in the Hot Service Facility at FSV in February 1982, 8 months after removal from the reactor. According to PSC, the activity of the test element block was 30 mR/hr gamma and 500 mR/hr beta at contact, and 20 mR/hr gamma with 250 mR/hr beta at one foot from the block.

Due to the low activity of the element, an individual was sent into the Hot Service Facility to manually remove the specimens using a special removal tool [2]. Removal of the specimens required approximately 15 minutes in the facility, resulting in a whole body dosage of 2 mR to the individual. After removal, the specimens were stored in H-451 graphite crucibles in a can and shipped to GA. When received at GA on March 15, 1982, the activity of the 16 specimens plus caps and spacers was 2.5 mR/hr gamma at 8 inches and 5 mR/hr beta at 8 inches.

4.2 Initial Inspection

Specimens were removed from 1 crucible at a time to maintain order and identity. Each specimen was visually inspected, measured, then sealed in a tared plastic bag and weighed. Measurements of outside diameter (O.D.) were made at three locations [5] using hand held micrometers. Length measurements were made at 2 locations [5] using a Heidenhein MT 10 electronic gage. Specimen weight was determined using a Sartorius microbalance accurate to 1×10^{-4} grams. Photographs were then made of each specimen.

4.3 Oxidation Profile

Oxidation profiles were measured on each specimen following the procedures of Ref. 6. In summary, the procedure consisted of dimensioning and weighing the specimens, then removing a thin (0.0025 to 0.005 inch) layer from the inner cylinder bore of the specimen and remeasuring and weighing the specimens. The density of the layer removed was calculated from the weight and measurements of the remaining specimen. This process was repeated for 10 to 30 layers, resulting in a profile of density (oxidized weight loss) versus distance from the original surface. The procedure is shown schematically in Figure 6.

Due to the slight radioactivity of the specimens, the profile determinations were performed in a glove box. One chamber of the glove box contained a precision lathe which was used to machine the layers from the inner bore. Machined specimens were transferred from the machining chamber through an isolation chamber into the measurement chamber of the glove box. In the measurement chamber, the inner diameters of the specimens were measured using a Mauser 6700/9H bore gage coupled to a Heidenhein electronic micrometer head. The resolution of the total measurement system was 1×10^{-3} mm. The thicknesses of the layers measured were 64×10^{-3} to 130×10^{-3} mm. Specimens were weighed on a Sartorius model 1207 MP2 balance which was mounted on isolation pads to minimize vibration. Resolution of weight was 2×10^{-4} grams, (approximately 0.2% of the minimum layer weight).

5. RESULTS

5.1 Specimen Removal

Removal of the PGX specimens from the test element block took less than 15 minutes. The specimen removal tool performed adequately, however the tool did not function smoothly in holes near the block edge (i.e., hole #VI). In several holes the tool had to be inserted and tripped several times to engage the spacer and lift the stack out. Two hands were required to remove 4 of the specimen stacks from the tool to the storage crucible. When specimens must be removed from test assemblies by remote devices, it will be necessary to use 2 fully articulated manipulators to complete the task.

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The overall appearance of the test element block was excellent.

5.2 Non-Destructive Examination

PIE measurements and weights of the surveillance specimens are summarized in Table 2. The specimens appeared to have grown a fraction of a percent. Specimen weight was 0.2 to 0.3 grams less than at insertion, a decrease of 0.8 to 1.2%. The specimen weight loss measured at the initial inspection (Table 3) and again at the start of the profile determination were in excellent agreement. The measured weight losses were about 20% of the predicted weight losses [3].

Overall weight loss in the PGX surveillance specimens averaged 0.80% in the 100 series (billet 138) specimens and 0.93% in the billet 112 specimens (Table 2). The billet 138 specimens showed little variation with a standard deviation between specimens of 0.02 wt % or 2.5% of the mean. Greater variation was noted in the billet 112 specimens which had a standard deviation of 0.16 wt % or 17% of the mean.

Visual examination of the PGX specimens revealed a distinct difference between the 200 series specimens (billet 6484-112) and the 100 series taken from billet 6484-138. The cylinder bore of the 200 number specimens appeared highly oxidized with a rough surface texture as shown in Figure 7a. The 100 series specimens exhibited less apparent surface oxidation as shown in Figure 7b. The difference in oxidized surface texture was apparent even in specimens which had the same total weight loss as shown in Figures 7c and 7d. Photographs of each of the 16 specimens are included in Appendix B.

5.3 Oxidation Profiles

All 16 PGX surveillance specimens were machined to determine the density profile (oxidation profile) relative to the original inner cylindrical bore of the specimen. Figure 8 summarizes the oxidation profiles measured on the 16 PGX specimens. The 200 series specimens from billet 6484-112 were oxidized to 30% to 45% weight loss at the coolant channel surface (inner cylinder bore), while the 100 series were oxidized to only 8% to 15% weight loss at the surface. The oxidation decreased rapidly with distance away from the surface in the 200 series. The 100 series specimens exhibited very flat oxidation profiles with oxidation levels of about 1% remaining at a distance of 1.2 mm (0.040 in.) away from the surface.

Oxidation profiles were plotted for each specimen in Figures 9 and 10. The data presented in Figures 9 and 10 were smoothed at measurements at which the Mauser bore gauge head was changed to the next largest head. Calibration runs with unoxidized graphite had shown I.D. measurement errors when the bore gage head was changed. The data were smoothed by deleting the weight and measurements at the point of the head change. As a result, the layer density calculated at that location was calculated from a double thickness layer.

After the specimens were machined to determine the oxidation profile, the remainder of each specimen was measured to calculate its density. The densities of the specimen remains were tabulated in Table 4 and translated to burnoff (density change). The 100 series specimens showed low levels of burnoff in the remaining material after the profiles had been measured.

5.4 Predictions

Results of the CSBBO-3 code calculations were well documented by Dunn [3]. Predicted weight losses for the surveillance specimens are summarized in Table 3 of this report. The most severe and least severe oxidation profiles predicted for the region 25 specimens are shown in Figure 8. In all cases, the CSBBO-3 code predicted higher levels of oxidation and more severe oxidation profiles than actually observed in the surveillance specimens.

6. DISCUSSION

6.1 Specimen Retrieval and Experimental Procedures

The overall retrieval and PIE of the surveillance specimens was performed smoothly according to plan. The tool used to remove the specimens from the test element block required 2 hands at times for successful operation. Due to the low radioactivity of the test elements, specimen retrieval will probably be best accomplished by manual removal of the specimens in the FSC Hot Service Facility. Should remote handling be required, 2 articulated manipulators will be necessary for easy operation of the removal tool.

During the PIE of the specimens, the largest and only significant systematic error was found in the measurement of the inner diameter of the cylindrical specimens. Oxidation profile determinations can vary by 2% burnoff for an error of only 0.0025 mm (0.0001 inches) in the I.D. measurement. The Mauser gage which was used had a resolution of 0.001 mm (0.00004 in.), however the oxidized graphite surface was easily indented by the gage head at points of contact, leading to errors in measurement. The errors were most pronounced when gage heads were changed because the next larger gage head exerted a higher indenting force against the graphite surface. Therefore the data were smoothed by deleting the weight and dimension measurements at the point of the head change. The resulting layer density was calculated from a double thickness layer. The potential for this problem was recognized in the early planning of this PIE and a non-contact laser metrology system was budgeted. The laser based system was not purchased due to vendor reservations regarding errors in specimen alignment and their effect on the accuracy of the laser measurement. However, such a measurement system, fitted with a custom alignment collett apparatus, should be seriously investigated for future PIE for two reasons: (1) potential improved accuracy of the measurement; and (2) adaptability to remote measurements.

6.2 Oxidation

Both the overall oxidation and the oxidation profiles observed in the PGX surveillance specimens were less severe than predicted. These results confirm the conservatism of the CSBBO-3 code predictions, which were based upon a design PGX oxidation rate of 1000 times the H-451 rate as shown by the solid lines in Figure 4. Laboratory oxidation tests of the PGX surveillance sample population [2] had resulted in measured oxidation rates which were less than the design rate as shown by the data in Figure 4. The surveillance results were qualitatively consistent with laboratory data.

The oxidation behavior of the PGX surveillance specimens removed from region 25 was similar to the behavior observed in high velocity laboratory oxidation tests at 700°C. In both the 700°C high velocity lab test specimens and the PGX surveillance specimens, the graphite from billet 112 displayed higher overall weight loss and steeper oxidation profiles. These results suggest that billet 112 specimens oxidized at faster oxidation rates than the billet 138 specimens. However, low velocity laboratory data showed the converse; billet 138 showed highest oxidation rates. These results illustrate the difficulties inherent in extrapolating laboratory oxidation results to describe behavior under reactor conditions. The laboratory test conditions which most closely simulated reactor conditions produced oxidation behavior similar to actual in-reactor oxidation, while typical standard oxidation tests were less discriminatory.

Differences between laboratory test results were probably due to changes in mass transport and in states of catalytic activity in the PGX graphite. Several studies [7-8] have found widely varied oxidation behavior in PGX graphite due to different test conditions. The results of PIE of region 25 confirm the importance of accurately modeling actual operating conditions when investigating oxidation behavior in the laboratory.

The PGX surveillance specimens removed from region 25 exhibited the same qualitative differences in weight loss as observed in oxidation rates from lab testing. The variation in overall weight loss in the billet 138 specimens was only 2.5% of the mean compared with a variation of 4.7% in the laboratory data. Specimens from billet 112 had a standard deviation in overall weight loss of 17% of the mean which was consistent with the 16% found in laboratory tests at 586 hours [2].

Likewise, the oxidation profiles found in the specimens differed considerably from billet 138 to billet 112. The 200 series specimens from billet 112 underwent up to 40% weight loss at the surface, but oxidation decreased rapidly away from the exposed surface (Figures 8,9). PGX billet 138 material experienced less than 20% weight loss at the surface, but the oxidation profile was much flatter (Figures 8,10). The difference in oxidation profiles most likely arose due to

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differences in mass transport and in the complex catalysis of oxidation in PGX. Billet 112 contained approximately twice the impurity level as billet 138 including significantly higher levels of Fe, S, and Cu (Table 5). Iron is a known catalyst for graphite oxidation.

Rapidly oxidizing graphite generally exhibits steeper oxidation profiles as observed in the 200 series surveillance specimens. In the 100 series specimens, low level oxidation extended further into the depth of the specimens as shown in Figure 8 and Table 4. The flatter profile with a longer tail is characteristic of more slowly oxidized graphite. However, the differences in overall oxidation between billet 112 and 138 material averaged only 18%, much less than would be expected on the basis of the oxidation profiles. The PIE of the next surveillance test element to be removed from the reactor (Region 30, refueling number 4) will show if the specimens from billets 112 and 138 continue to exhibit approximately equal overall burnoff.

Due to the difficulties of I.D. measurement, the accuracy in determination of burnoff was about ±2% burnoff. At the tail end of the oxidation profiles, the slope of the actual profile was difficult to determine due to the inaccuracies. In the billet 112 specimens (200 series) the profile was steep enough to be determined quite accurately. However, the shallow slope of the billet 138 specimens made the profile determination more difficult. Consequently, the burnoff remaining in the specimens at the end of the profile determination was tabulated in Table 4.

The profile data combined with Table 4 indicate that the oxidation penetration of the 112 billet specimens had ended at depths of 0.9 to 1.1 mm. In the billet 138 material, the oxidation penetration still existed at depths of 1.5 to 2 mm although the level of burnoff was only 0.5 to 1.5 wt %. In both cases, the depth at which oxidation equaled 1 wt % was considerably less than the 2.3 mm predicted by CSBBO-3 code.

The surveillance specimens from region 25 experienced considerably less oxidation than predicted by the CSBBO-3 code. Strength and modulus of oxidized PGX graphite can be calculated according to Equation (1) [7].

$$\frac{S}{S_o} = \exp^{-mx} = \frac{E}{E_o} \qquad (1)$$

where

S, E = strength, or modulus, of oxidized graphite

S_o, E_o = strength, or modulus, of unoxidized graphite

X = oxidation level (fractional burnoff, i.e., 10% = 0.10)

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$m = 5$ for PGX.

The strength or modulus of PGX graphite containing an oxidation profile can be calculated from Equation (1) at increments along the oxidation profile [7]. Since the experimentally observed oxidation profiles of the surveillance specimens were considerably less severe than predicted by CSBBO-3 code, the actual reduction in graphite strength was also much less than would have been predicted.

7. CONCLUSIONS

PGX surveillance specimens removed from region 25 exhibited significantly less oxidation than predicted. Overall oxidized weight loss averaged only 20% of the predicted values. Actual penetration depth of oxidation into the specimens was only about 50% of predictions and the level of burnoff in the oxidized volumes was considerably lower than predicted.

The CSBBO-3 code conservatively modeled the behavior of the PGX specimens in reactor. Code predictions and experimental measurements were in good qualitative agreement. Quantitative errors were probably primarily due to conservatism in the assumed oxidation rate.

PIE methodology worked well. A non-contact, highly accurate method for measurement of specimen inner diameter could increase the accuracy of the measured profiles, particularly in the low burnoff tails.

Laboratory oxidation experiments must approximate actual reactor conditions to accurately predict graphite oxidation behavior. The better the laboratory approximation to reactor conditions, the better the correlation between laboratory and in-reactor behavior.

8. REFERENCES

1. "Test Plan for In-Reactor Surveillance of Grade PGX Graphite," Document 18-R-29/A, December 12, 1978.

2. "FSV PGX Surveillance - Final Report," Document 17-R-18/A, August 7, 1979.

3. "Prediction of Graphite Burnoff in FSV Surveillance Samples - Cycle 2," Document 906223/A, September 25, 1981.

4. "Test Specification for PIE of PGX Surveillance Specimens (Region 25)," Document 906099/A, August 25, 1981.

5. "Procedure for Nondestructive Examination of PGX Surveillance Specimens," Document TP-061, February 9, 1979.

6. "Procedure: Oxidation Profile Determination for PGX Surveillance Test," Document TP-059, January 19, 1979.

7. Price, R.J. and L.A. Beavan, "Strength of Nonuniformity Oxidized PGX Graphite," GA-A16270, May 1981.

8. Morgan, W.C. and M.T. Thomas, "The Inverse Oxidation Phenomenon," Carbon,

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Table 1. Preirradiation Characterization of PGX Surveillance Specimens.

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OPERATOR King
RECORDER Campbell
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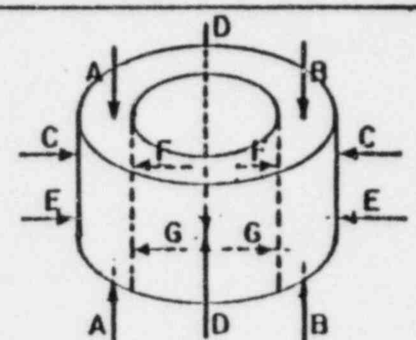

ALL MEASUREMENTS ARE IN INCHES

SPECIMEN NUMBER	LENGTH A-A	LENGTH B-B	OUTSIDE DIAMETER C-C	OUTSIDE DIAMETER D-D	OUTSIDE DIAMETER E-E	INSIDE DIAMETER F-F	INSIDE DIAMETER G-G	WEIGHT GRAMS	~~VISUAL APPEARANCE~~ Density	
T100A	.8752	.8752	1.2980	1.2988	1.2990	.6258	.6258	25.3369	1.737	
T200A	.8757	.8757	1.2987	1.2985	1.2988	.6258	.6257	25.9095	1.775	
T104C	.8754	.8753	1.2992	1.2991	1.2990	.6260	.6260	25.3826	1.739	
T204C	.8757	.8756	1.2993	1.2993	1.2992	.6259	.6257	25.9219	1.774	
T210B	.8757	.8756	1.2993	1.2993	1.2994	.6260	.6258	25.9925	1.779	
T110B	.8754	.8753	1.2992	1.2993	1.2993	.6258	.6259	25.4460	1.742	
T214D	.8757	.8757	1.2989	1.2988	1.2986	.6257	.6257	25.9575	1.778	
T114D	.8753	.8753	1.2992	1.2993	1.2991	.6258	.6258	25.3799	1.738	
T120A	.8757	.8756	1.2990	1.2987	1.2988	.6259	.6258	25.4022	1.740	
T220A	.8757	.8756	1.2989	1.2988	1.2987	.6258	.6258	25.8799	1.773	
T124C	.8756	.8756	1.2991	1.2992	1.2992	.6259	.6259	25.4392	1.742	
T224C	.8757	.8756	1.2994	1.2993	1.2992	.6258	.6258	25.9431	1.775	
T230B	.8757	.8756	1.2992	1.2993	1.2993	.6260	.6258	25.9557	1.777	
T130B	.8755	.8756	1.2993	1.2992	1.2994	.6260	.6259	25.4968	1.745	
T234A	.8748	.8747	1.2985	1.2988	1.2987	.6258	.6258	25.8871	1.776	
T134D	.8758	.8757	1.2991	1.2991	1.2991	.6261	.6258	25.4430	1.742	

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Table 2. Region 25 PGX Surveillance Specimens Postirradiation Dimensions and Weight

SPECIMEN	WEIGHT PRE (g)	WEIGHT POST (g)	WEIGHT Δ (%)	LENGTH PRE (in)	LENGTH POST (in)	LENGTH Δ (%)	OUTSIDE DIAMETER PRE (in)	OUTSIDE DIAMETER POST (in)	OUTSIDE DIAMETER Δ (%)
T100A	25.3369	25.1251	-0.84	0.8752	0.8758	0.07	1.2986	1.2992	0.05
T200A	25.9095	25.6040	-1.18	0.8757	0.8768	0.13	1.2987	1.2991	0.03
T104C	25.3826	25.1818	-0.79	0.8754	0.8763	0.10	1.2991	1.2994	0.02
T204C	25.9219	25.7331	-0.73	0.8757	0.8769	0.14	1.2992	1.2994	0.02
T210B	25.9925	25.7096	-1.09	0.8757	0.8765	0.09	1.2993	1.2994	0.01
T110B	25.4460	25.2554	-0.75	0.8754	0.8760	0.07	1.2993	1.2995	0.02
T214D	25.9575	25.7067	-0.97	0.8757	0.8761	0.05	1.2988	1.2990	0.02
T114D	25.3799	25.1749	-0.81	0.8753	0.8767	0.16	1.2992	1.2992	0.0
T120A	25.4022	25.1972	-0.81	0.8757	0.8760	0.03	1.2988	1.2991	0.01
T220A	25.8799	25.6420	-1.07	0.8757	0.8763	0.07	1.2988	1.2993	0.04
T124C	25.4392	25.2404	-0.78	0.8756	0.8775	0.22	1.2992	1.2995	0.02
T224C	25.9431	25.7414	-0.78	0.8757	0.8762	0.06	1.2993	1.2993	0.0
T230B	25.9557	25.7433	-0.82	0.8757	0.8762	0.06	1.2993	1.2994	0.01
T130B	25.4968	25.2898	-0.81	0.8755	0.8762	0.08	1.2993	1.2995	0.02
T234D	25.8871	25.6657	-0.86	0.8748	0.8751	0.03	1.2987	1.2990	0.02
T134D	25.4430	25.2384	-0.80	0.8758	0.8760	0.02	1.2991	1.2993	0.02
Mean 100's			-0.80 ± .02			+0.09 ± .07			+0.02 ± .01
Mean 200's			-0.93 ± .16			+0.08 ± .04			+0.02 ± .01
Mean			-0.86 ± .13						

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Table 3. Region 25 PGX Specimen Weight Changes

	Weight Loss (%)	
SPECIMEN	CSBBO-3 PREDICTION	MEASURED INITIAL INSPECTION
T100A	4.2	0.84
T200A	4.2	1.18
T104C	4.4	0.79
T204C	4.4	0.73
T210B	4.8	1.09
T110B	4.8	0.75
T241D	4.1	0.97
T114D	4.1	0.81
T120A	4.9	0.81
T220A	4.9	1.07
T124C	3.8	0.78
T224C	3.8	0.78
T230B	4.3	0.82
T130B	4.3	0.81
T234D	4.3	0.86
T134D	4.3	0.80

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Table 4. Oxidation Remaining in Specimens After Profiles Cut

SPECIMEN	DEPTH AT END OF PROFILE (mm)	BURNOFF IN REMAINING SPECIMENS (wt %)
T100A	1.6	0.41
T200A	1.6	0.23
T104C	2.3	0.47
T204C	2.3	0.15
T210B	2.3	0.19
T110B	2.3	0.23
T214D	2.1	0.12
T114D	2.0	0.24
T120A	1.2	0.40
T220A	1.2	0.17
T124C	2.2	0.12
T224C		N/A
T230B	1.6	0.08
T130B	1.6	0.36
T234D	2.1	-0.18
T134D	2.2	0.32

Table 5. Summary of Characterization for Impurities in PGX Sample

Log		Impurity (ppm)													
		Ash	S	Fe	Al	Ba	Ca	Cu	Mg	Mn	Ni	Si	V	Ti	Zn
6484-112	Mean	6386	639	3043	225	100	250	140	75	75	75	97	50	50	31
	Std Dev	106	26	101	79	–[a]	–	150	–	–	–	66	–	–	23
6484-138	Mean	2506	<10	988	250	100	227	10	10	10	41	46	50	50	<20
	Std Dev	226	–	76	–	–	73	–		–	19	13	–	–	–

[a] Where standard deviation is listed as "-", all reported values for impurity element concentrations were equal in the log sampled.

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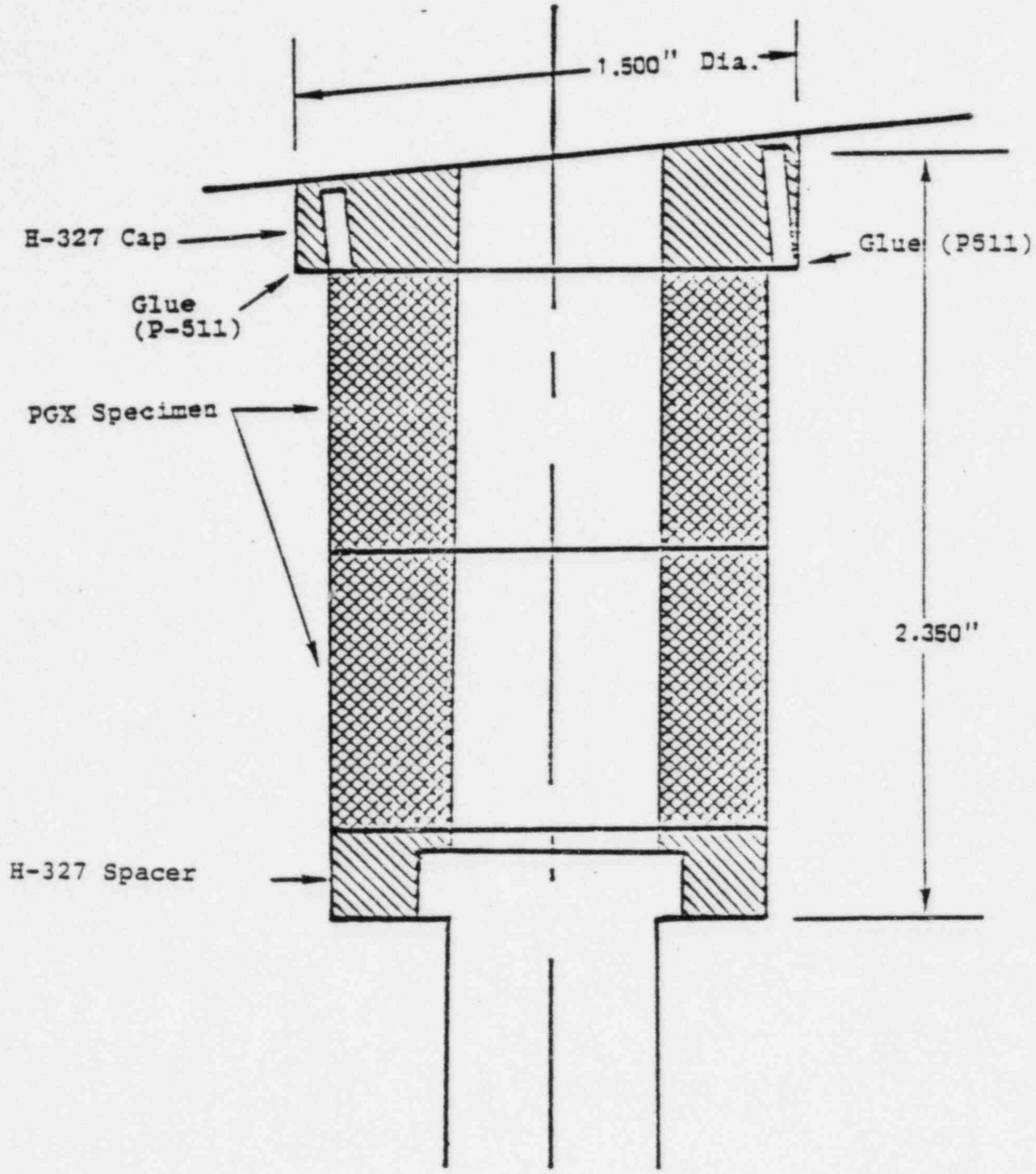

Figure 2. PGX Surveillance Test Assembly

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Region 25 Column 7

Block Serial # 5615686B Date 12-12-78

Assembly # R-90-1 1

Assembler C.H. Richards

Engineer L.A. Beavan QC Inspector L. Beavan

Hole	Spacer	PGX Insert Bottom	PGX Insert Top	Cap	Glued Cap	Comments
I	✓	T200A	T100A	✓	✓	Holes I - VIII primed
II	✓	T204C	T104C	✓	✓	at once. Caps I, III, IV, V, and VI
III	✓	T110B	T210B	✓	✓	primed + glued together at same time. Caps for holes II,
IV	✓	T114D	T214D	✓	✓	VII, and VIII primed and glued separately
V	✓	T220A	T120A	✓	✓	
VI	✓	T224C	T124C	✓	✓	
VII	✓	T130B	T230B	✓	✓	
VIII	✓	T134D	T234D	✓	✓	

QC Hold Points

1. PGX specimen identity (2.2.3) same as required by Table 2, 18-R-29 [signature] QC Inspector
2. Spacers and correct PGX specimen loaded in proper holes I through VIII [signature] QC Inspector
3. Inspection of final assembly [signature] QC Inspector

Figure 3. Region 25 Assembly Record

Notations in this column indicate where changes have been made

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No. 906624 Issue A

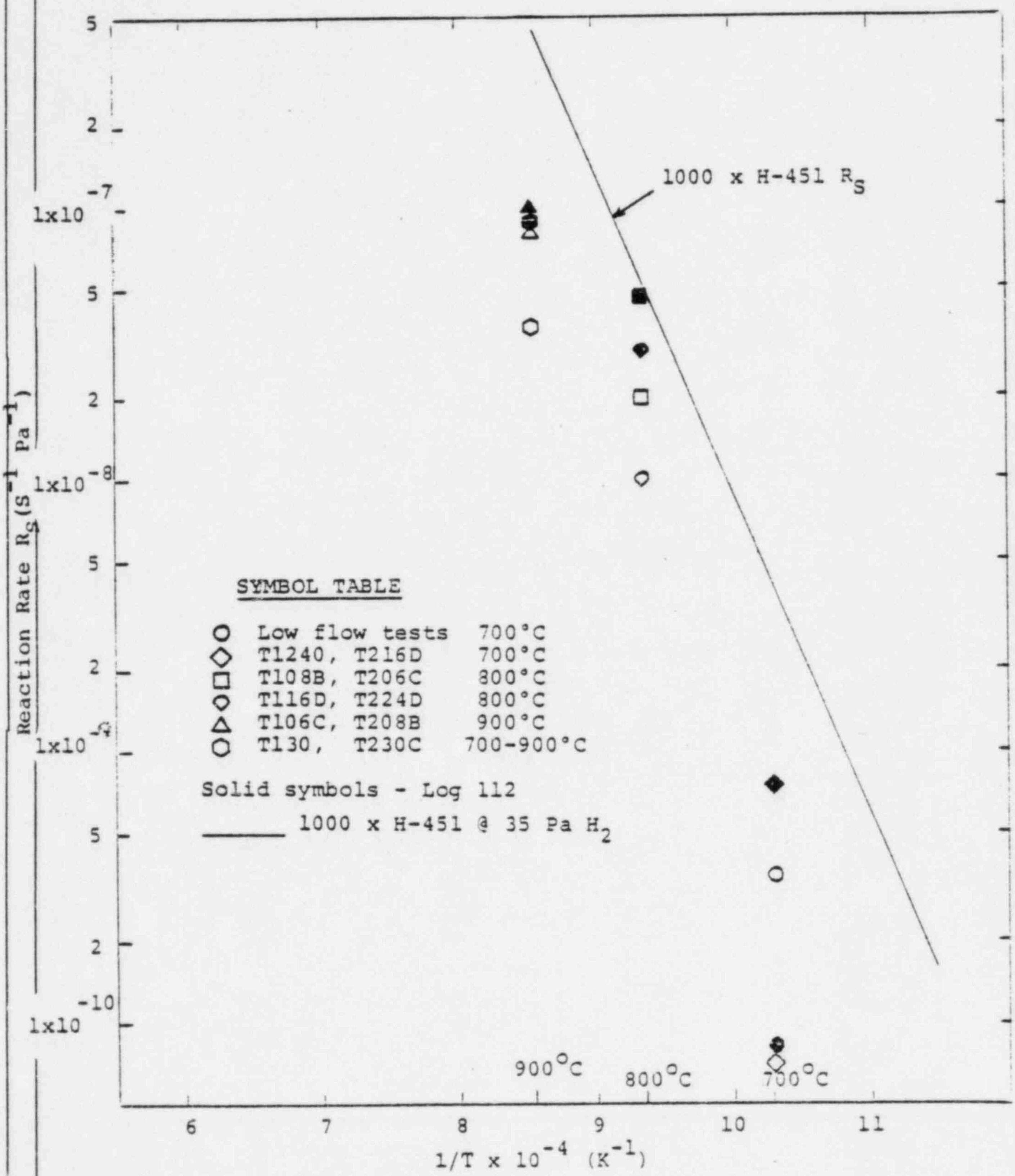

Figure 4. Oxidation Rates of PGX - Laboratory Data

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No. 906624 Issue A

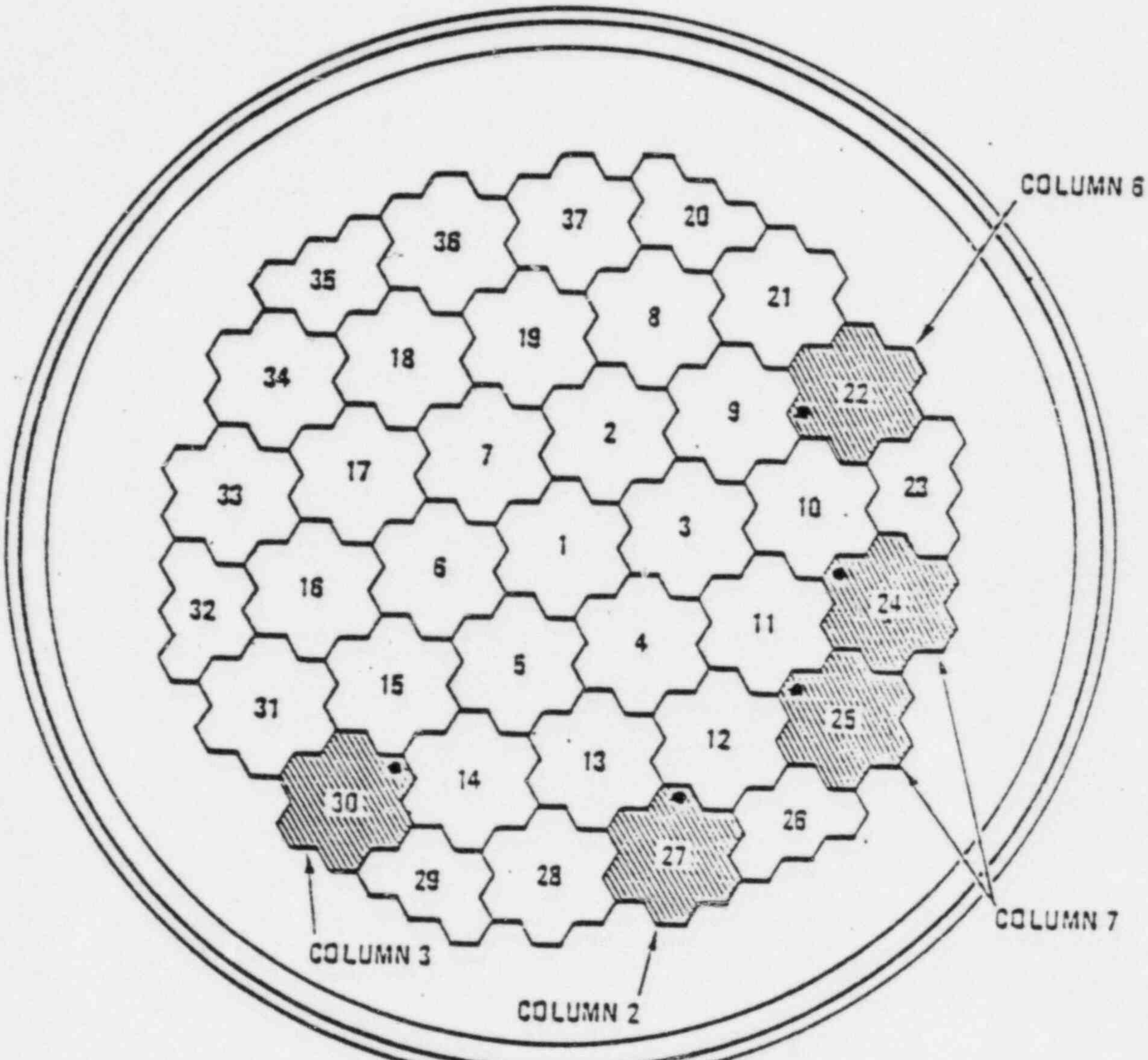

Figure 5. Location of PGX Surveillance Elements

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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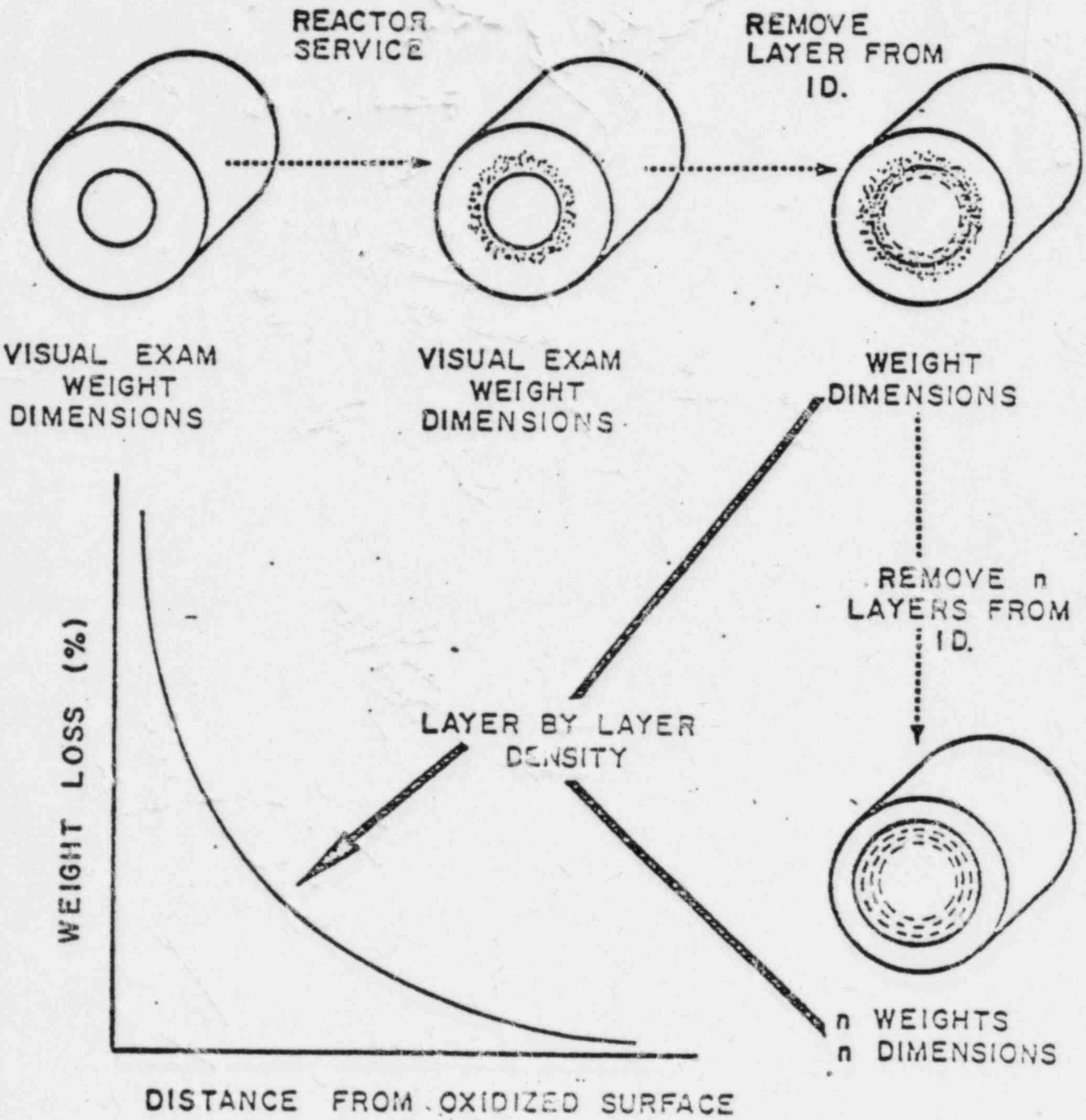

Figure 6. Postirradiation Examination Technique

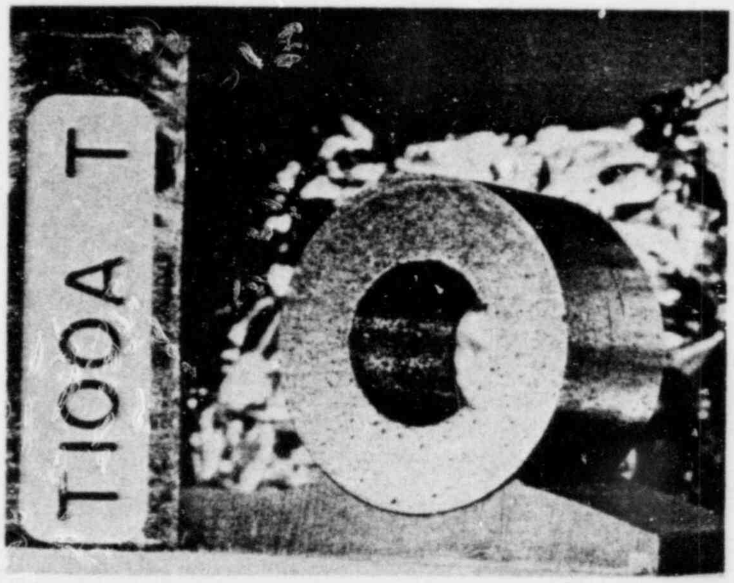

Figure 7a Appearance of Surveillance Specimens after Reactor Service
(a) T200A, (b) T100A

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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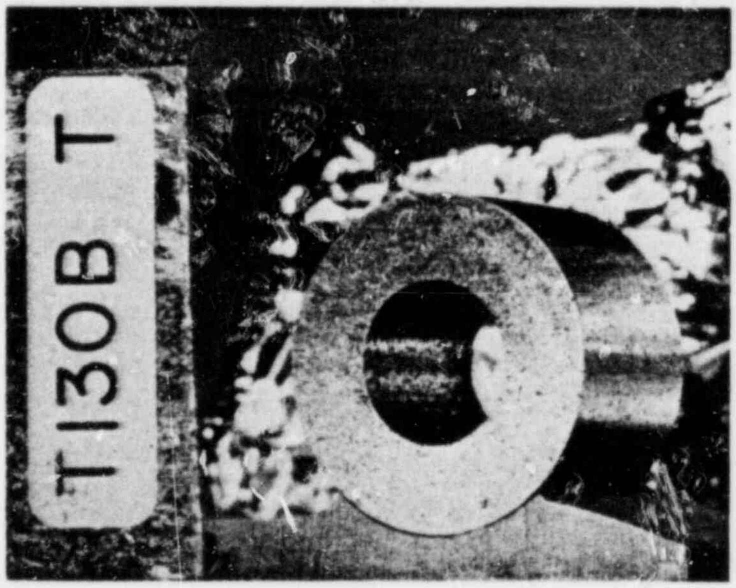

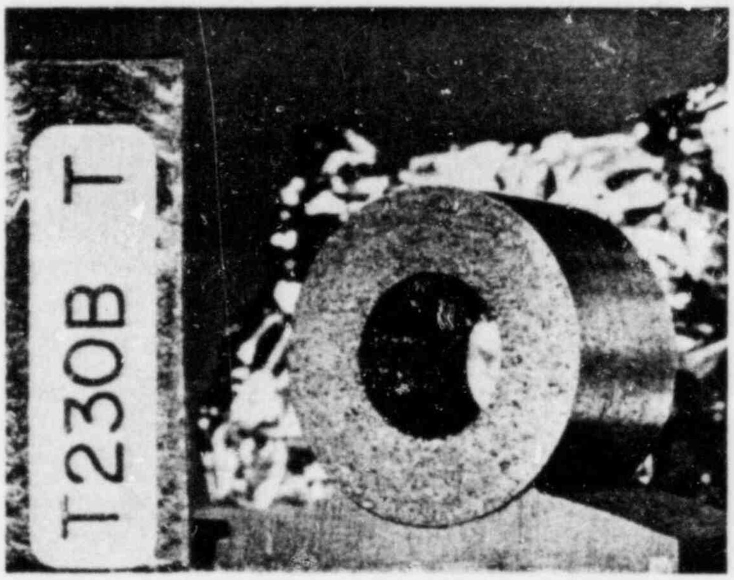

Figure 7b Appearance of Surveillance Specimens after Reactor Service (a) T230B, (b) T130B

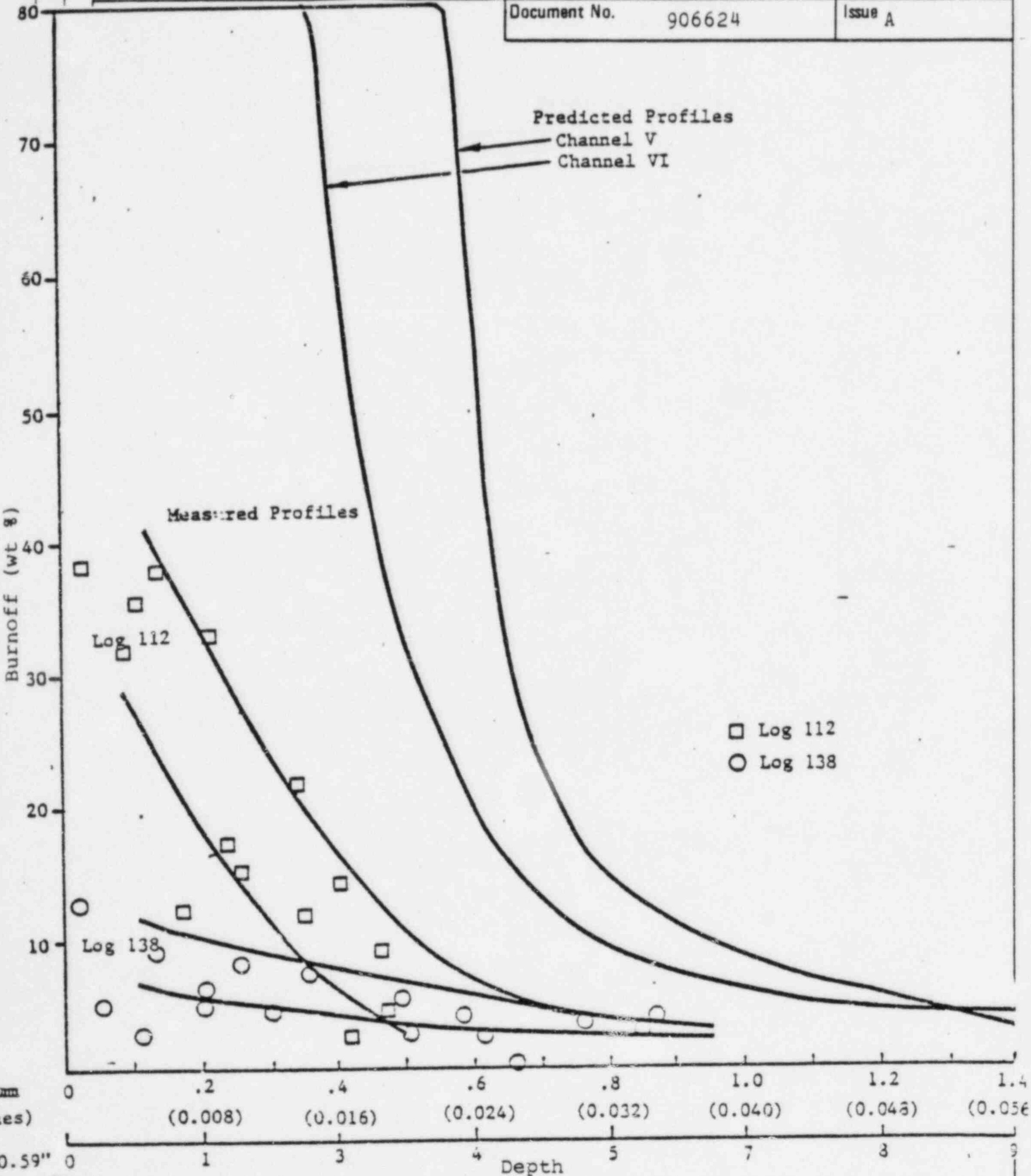

Figure 8. Predicted vs Measured Burnoff Profiles of PGX Surveillance Specimens (Region 25)

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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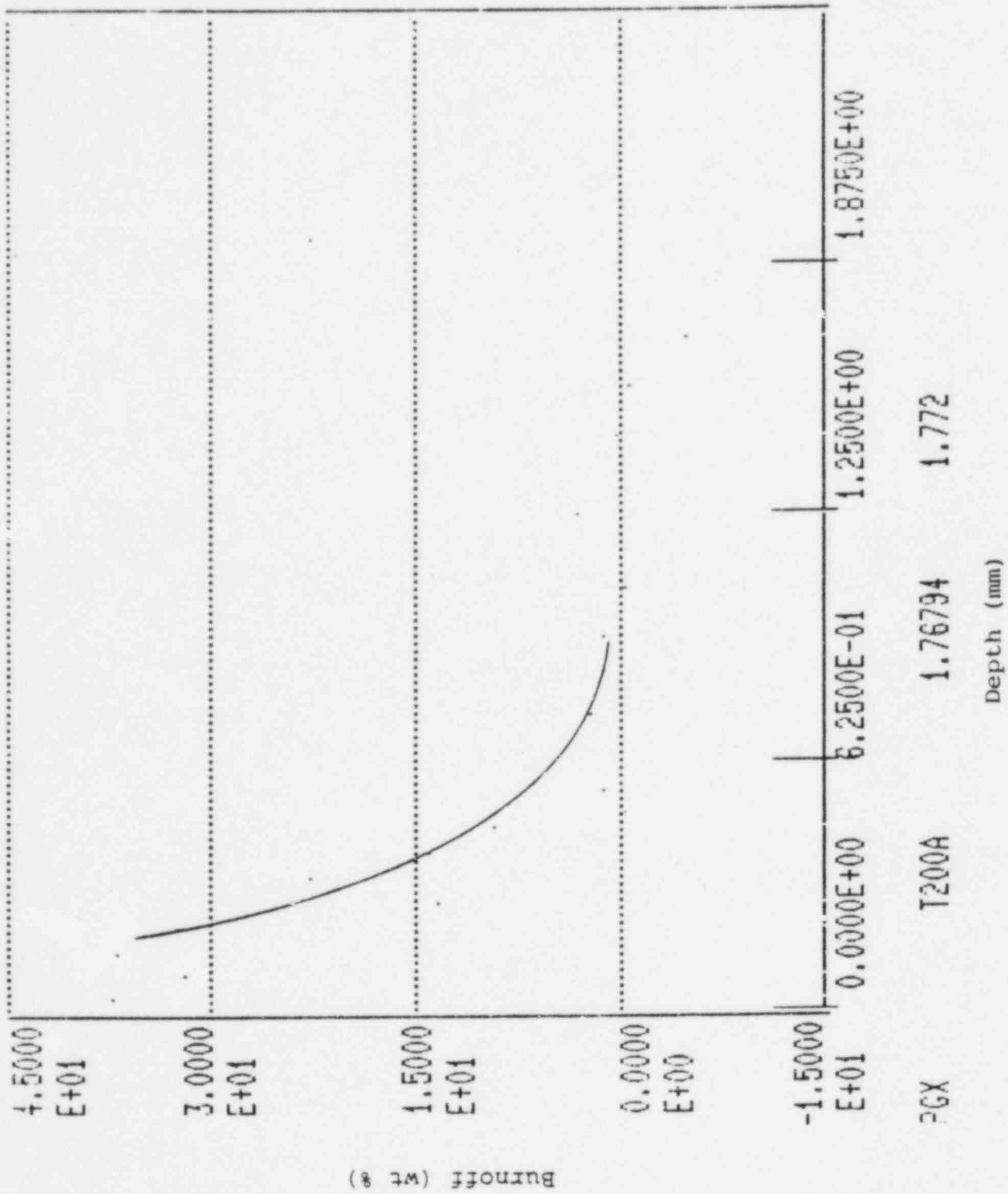

Figure 9(a) Oxidation Profile, Specimen T200A

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No. 906624	Issue A

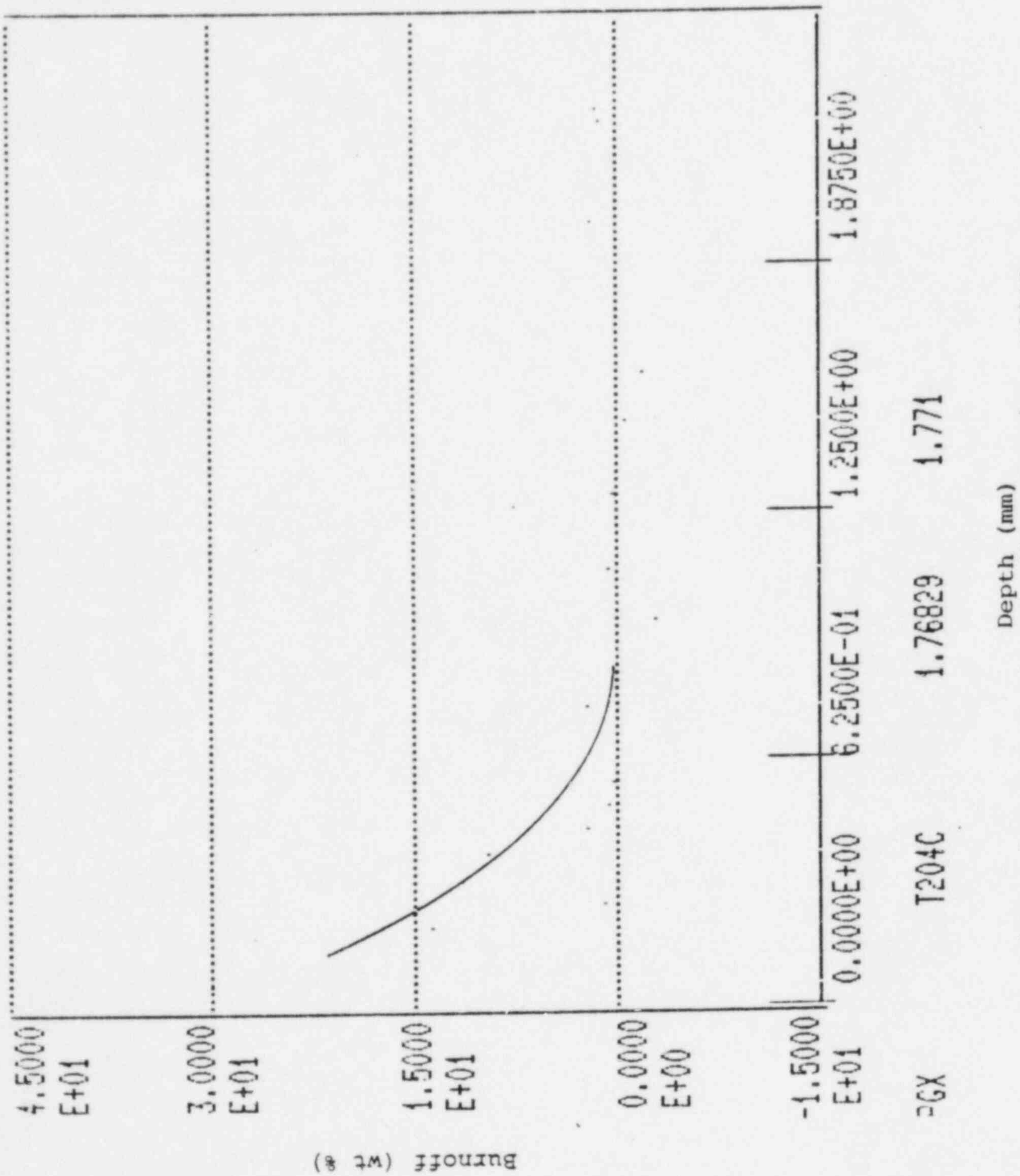

Figure 9(b) Oxidation Profile, Specimen T204C

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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Notations in this column indicate where changes have been made

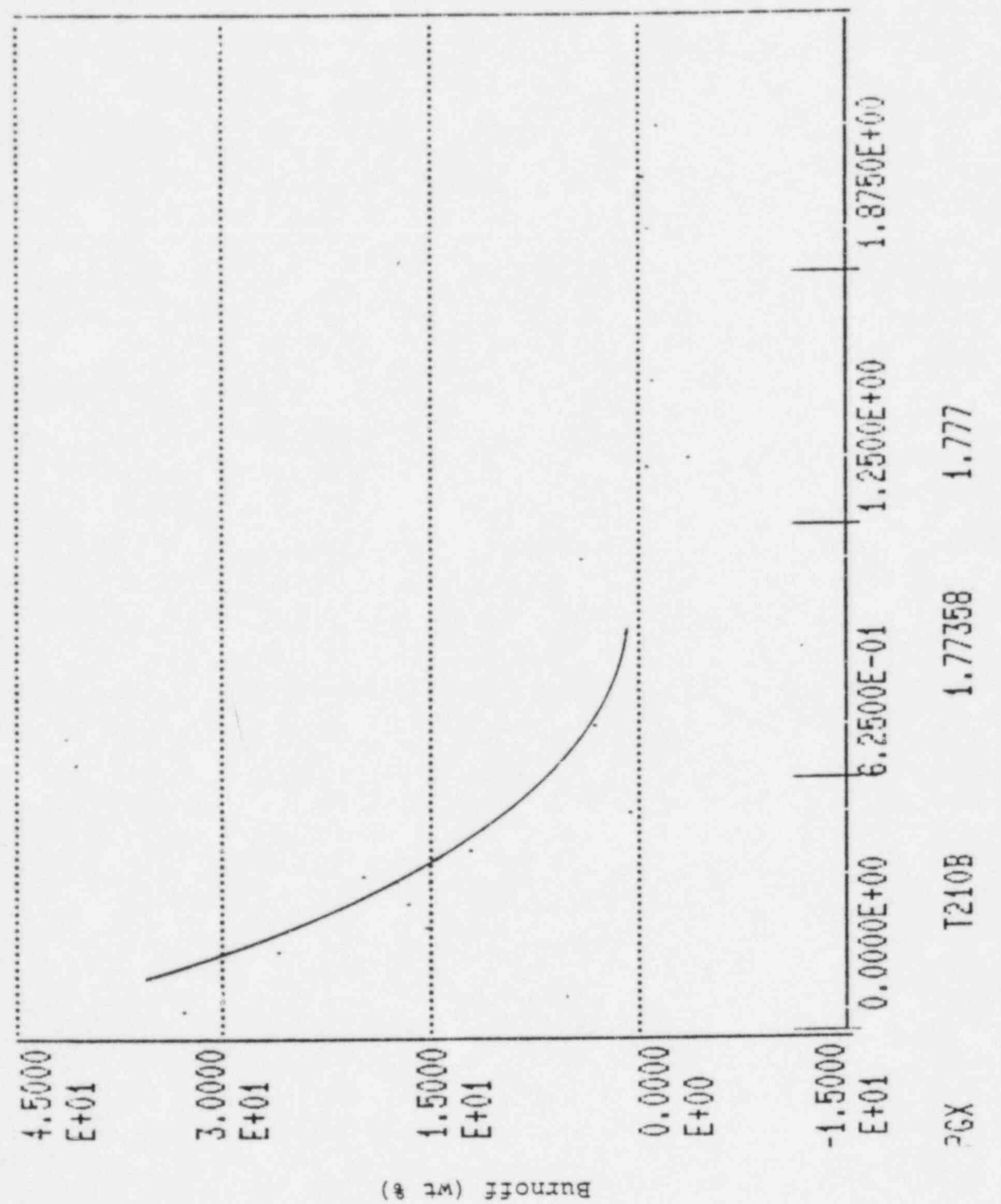

Figure 9(c). Oxidation Profile, Specimen T210B

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE FORT ST VRAIN REGION 25		
	Document No. 906624	Issue A

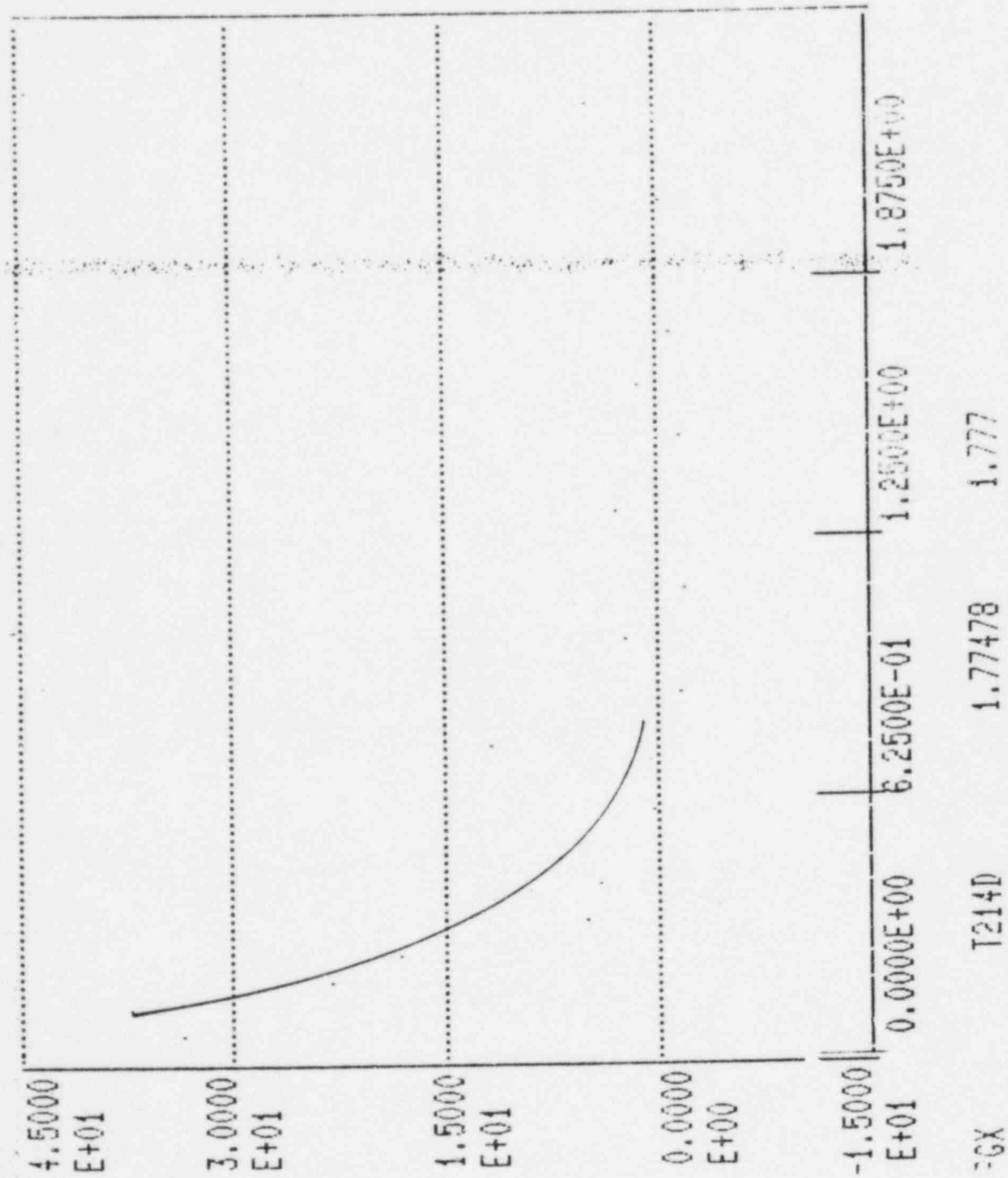

Figure 9(d). Oxidation Profile, Specimen T214D

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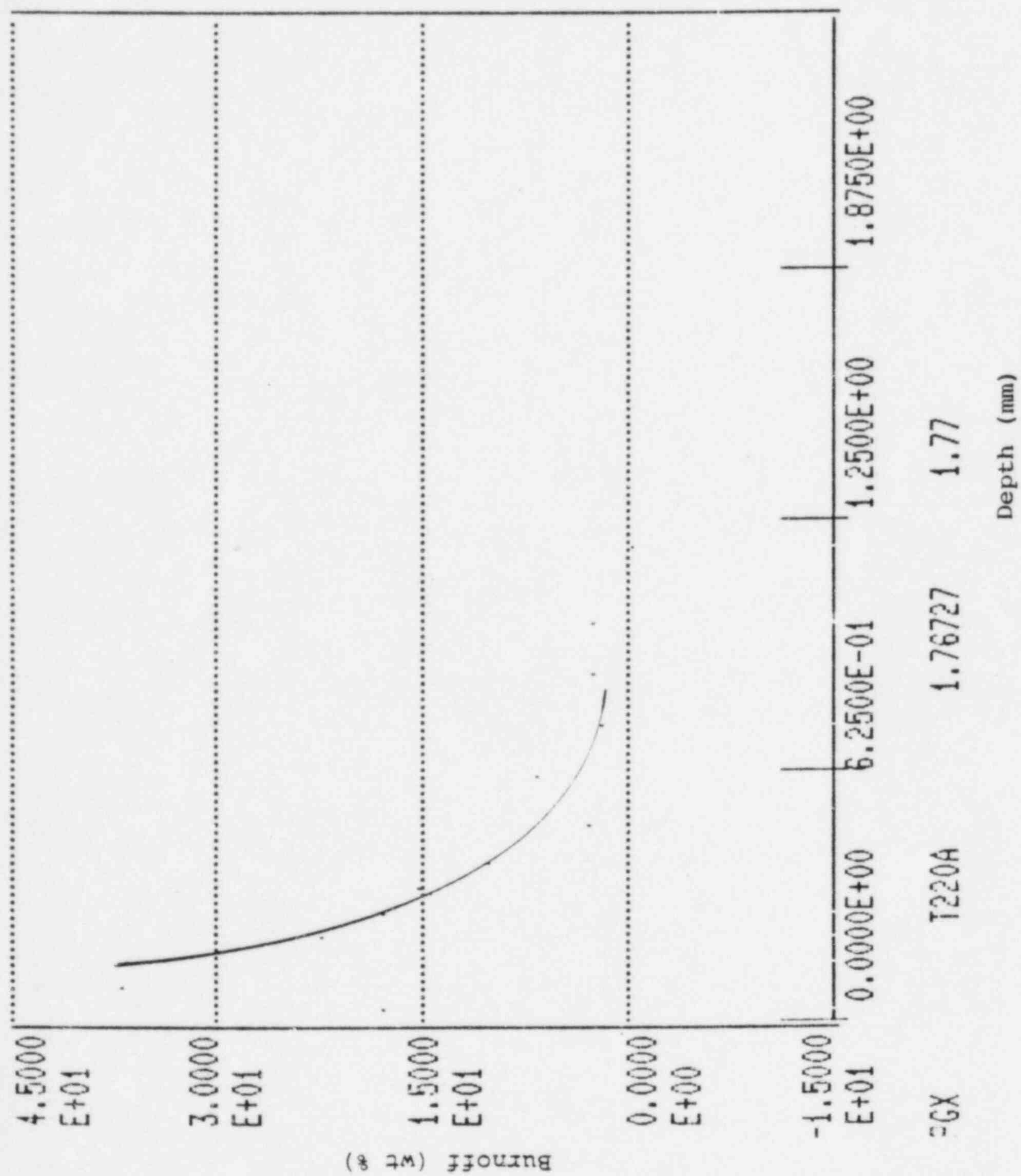

Figure 9(e). Oxidation Profile, Specimen T220A.

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No.	Issue
906624	A

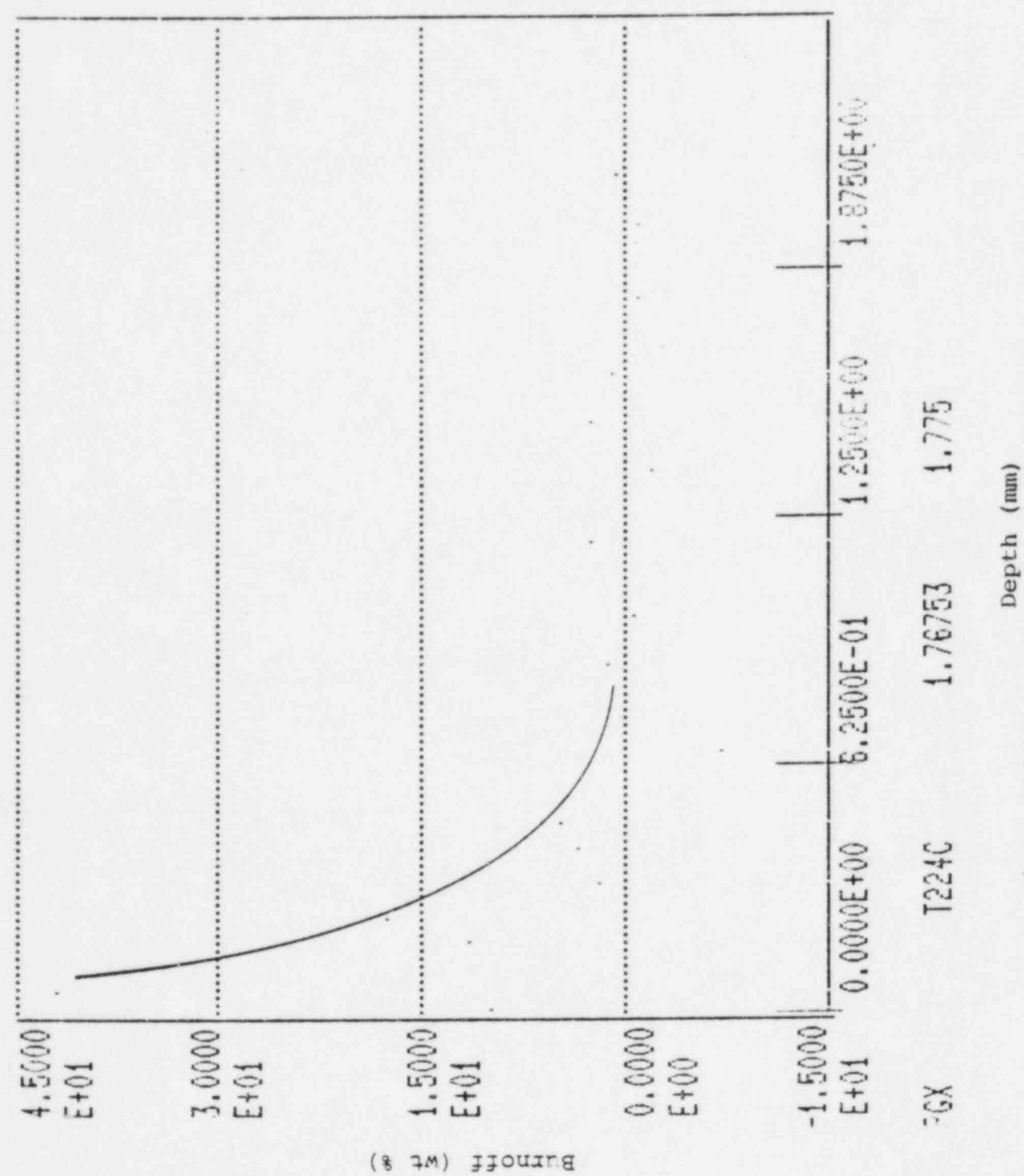

Figure 9(f). Oxidation Profile, Specimen T224C.

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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Notations in this column indicate where changes have been made

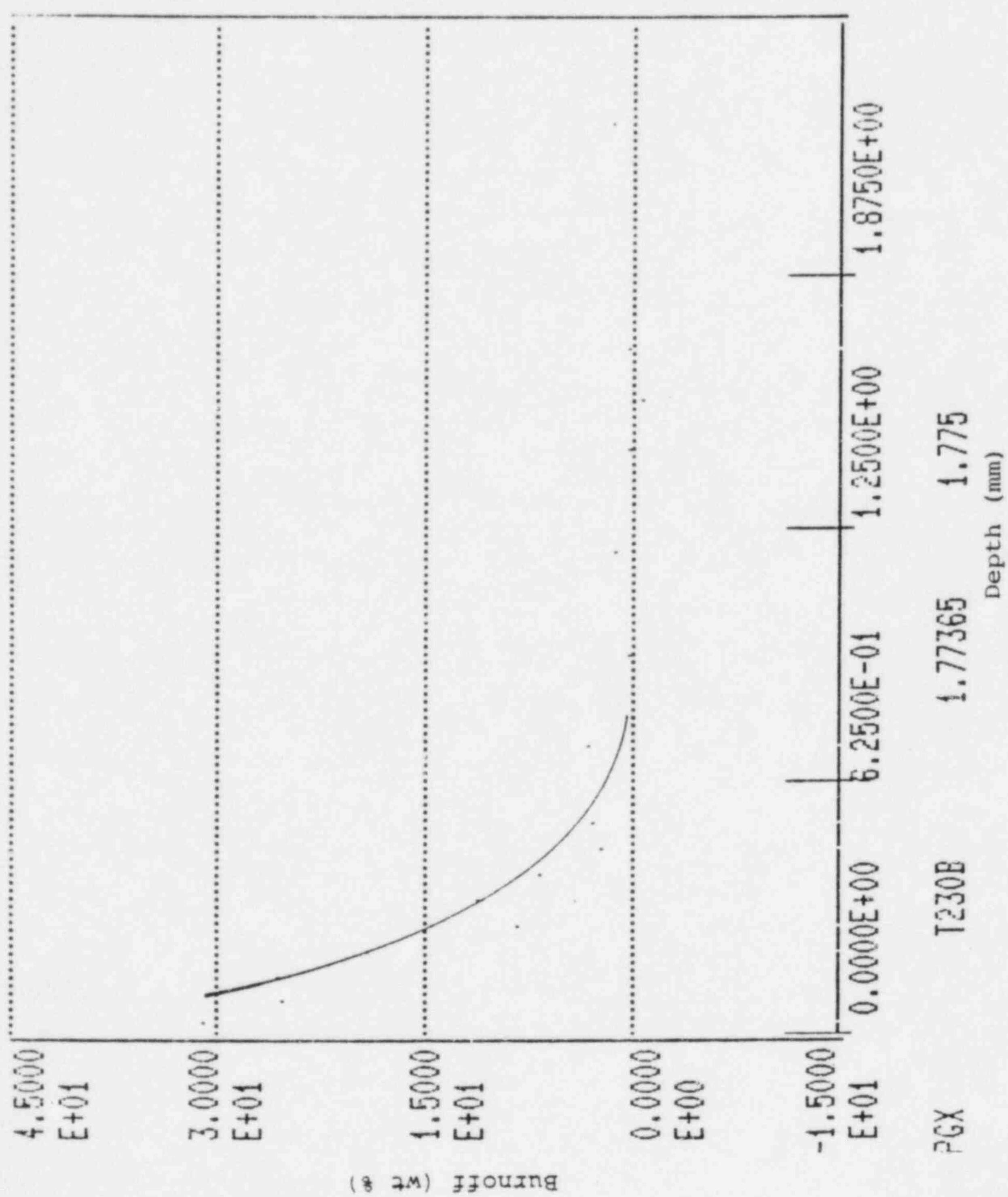

Figure 9(g). Oxidation Profile, Specimen T230B.

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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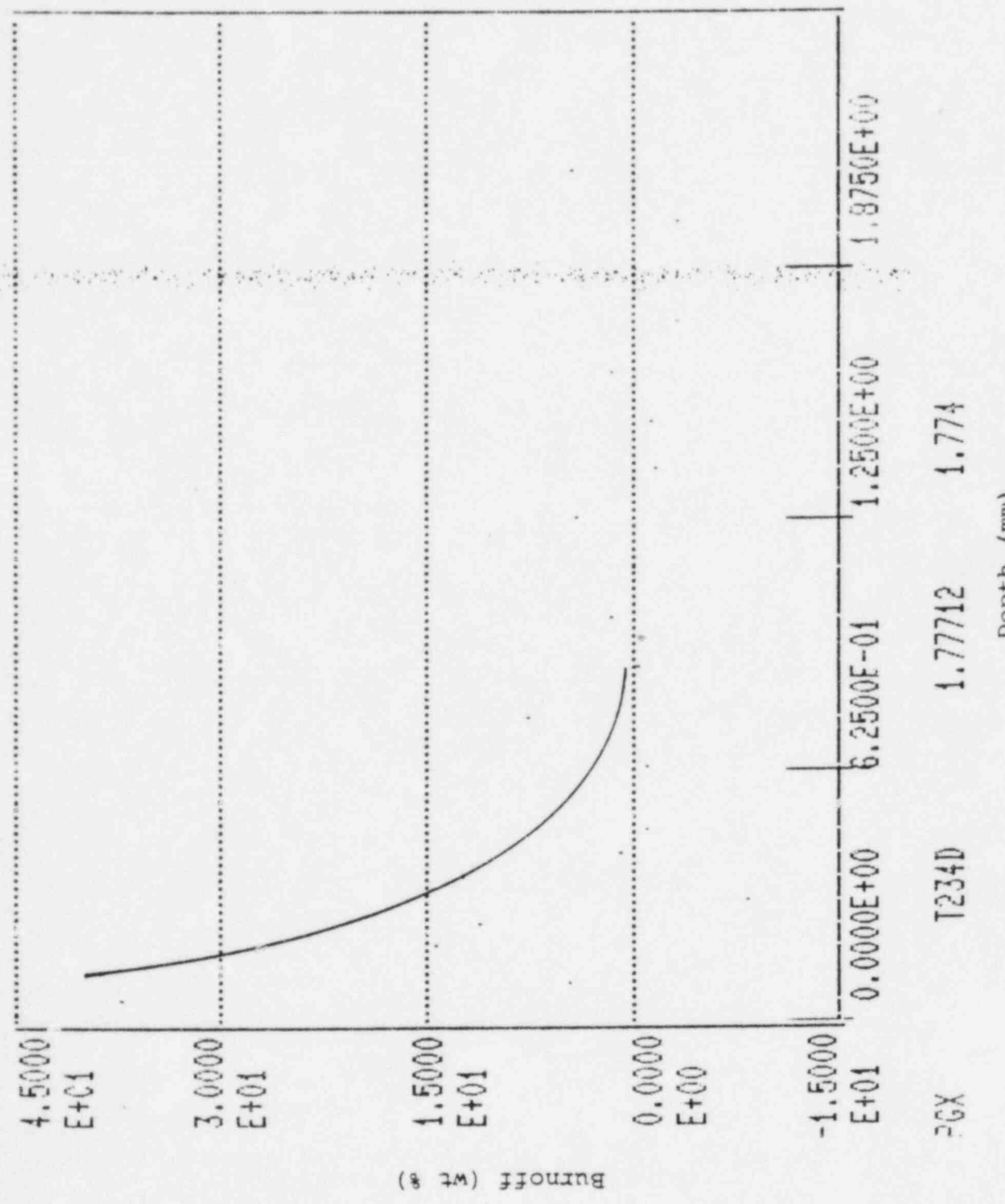

Figure 9(h). Oxidation Profile, Specimen T234D.

Notations in this column indicate where changes hav been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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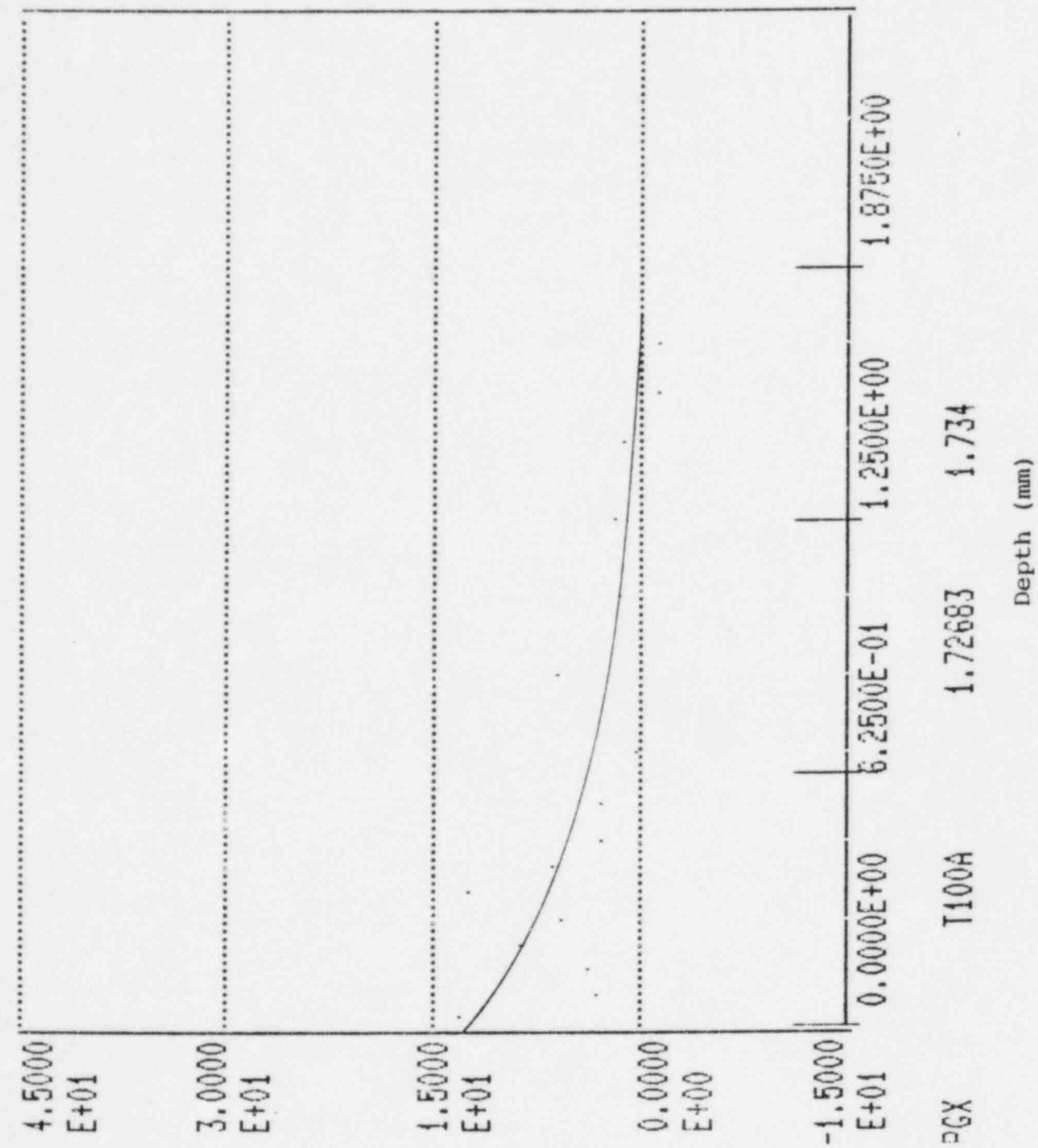

Figure 10(a). Oxidation Profile, Specimen T100A

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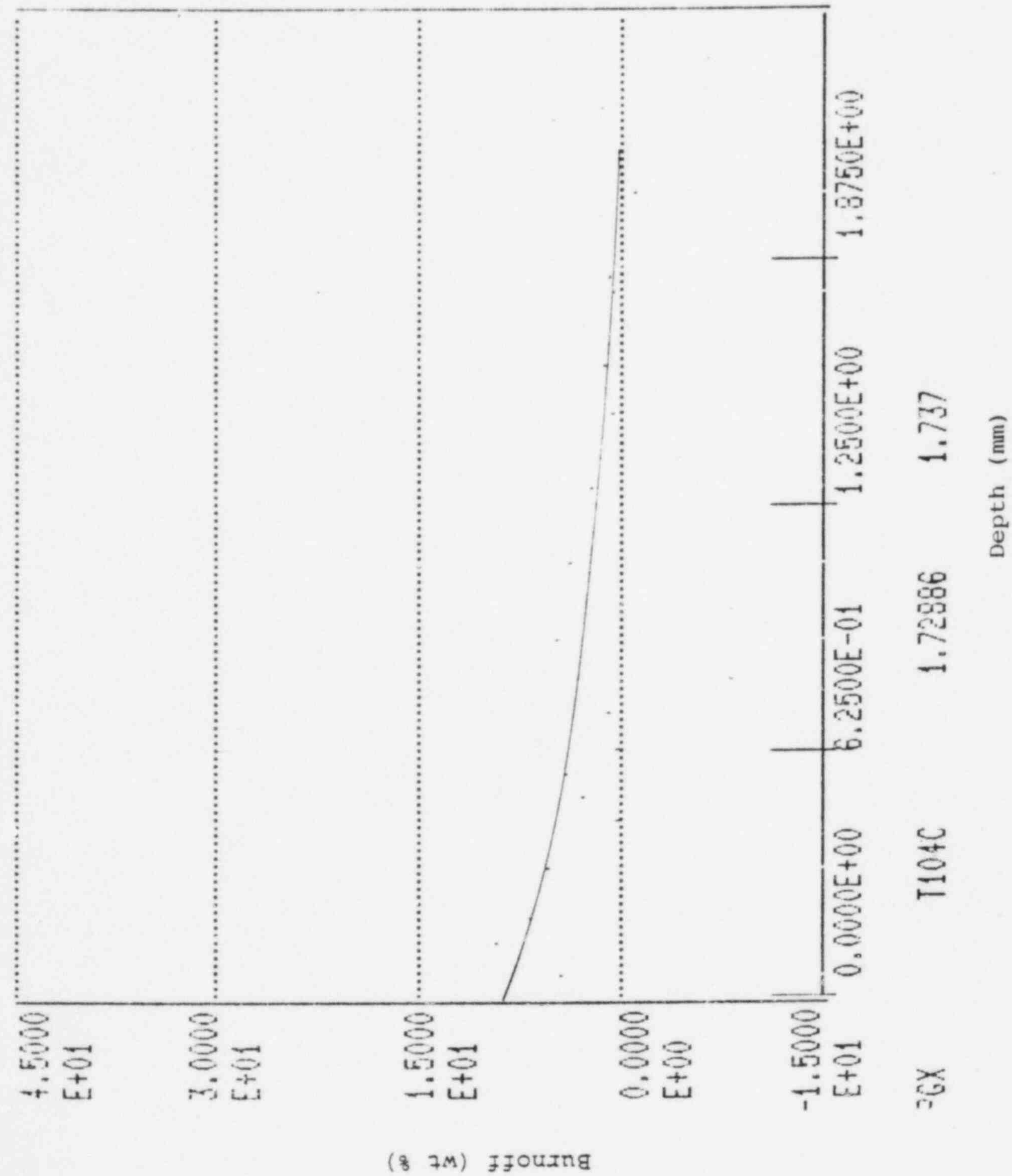

Figure 10(b). Oxidation Profile, Specimen T104C

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE FORT ST VRAIN REGION 25

Document No. 906624 Issue A

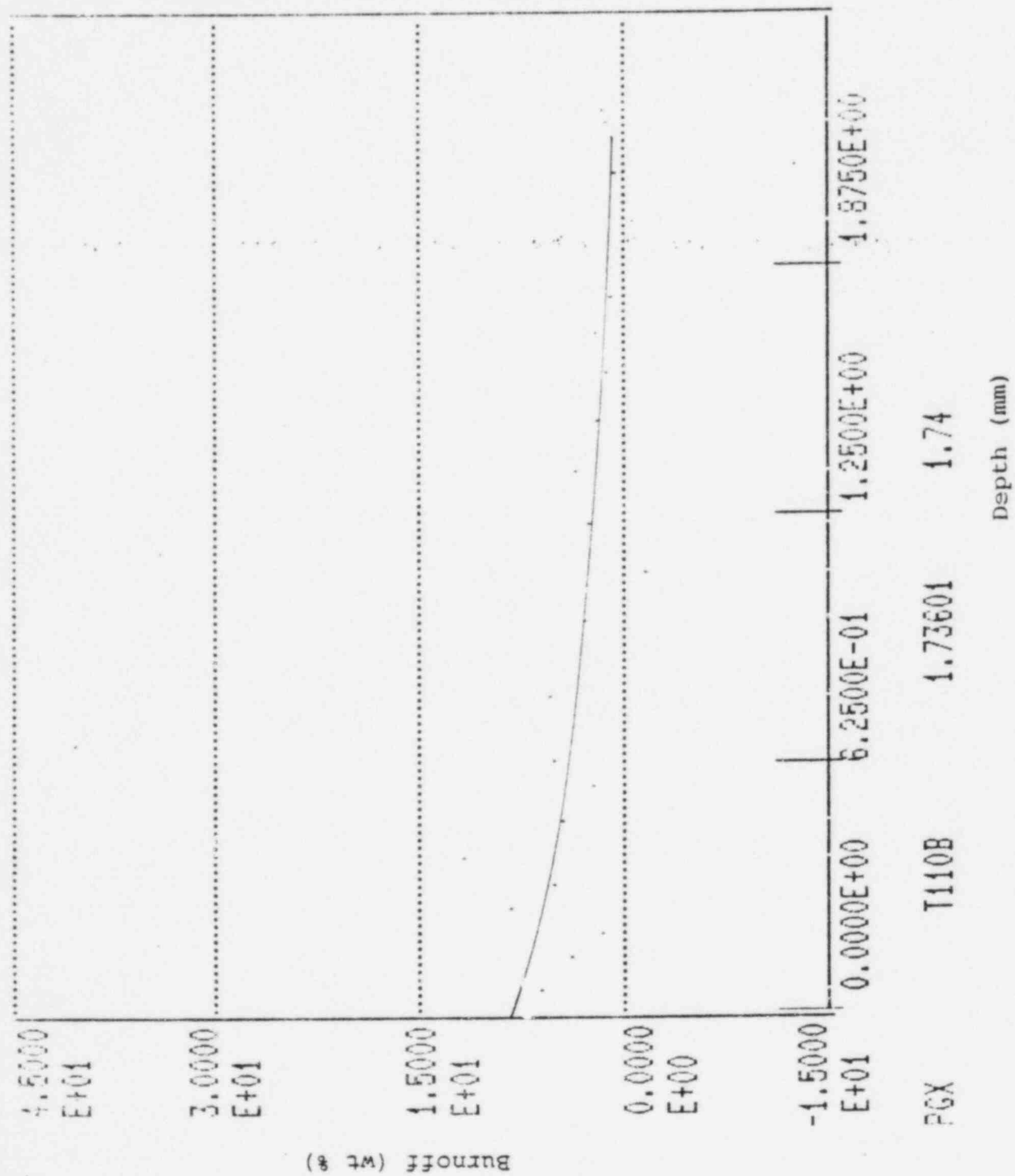

Figure 10(c). Oxidation Profile, Specimen T110B.

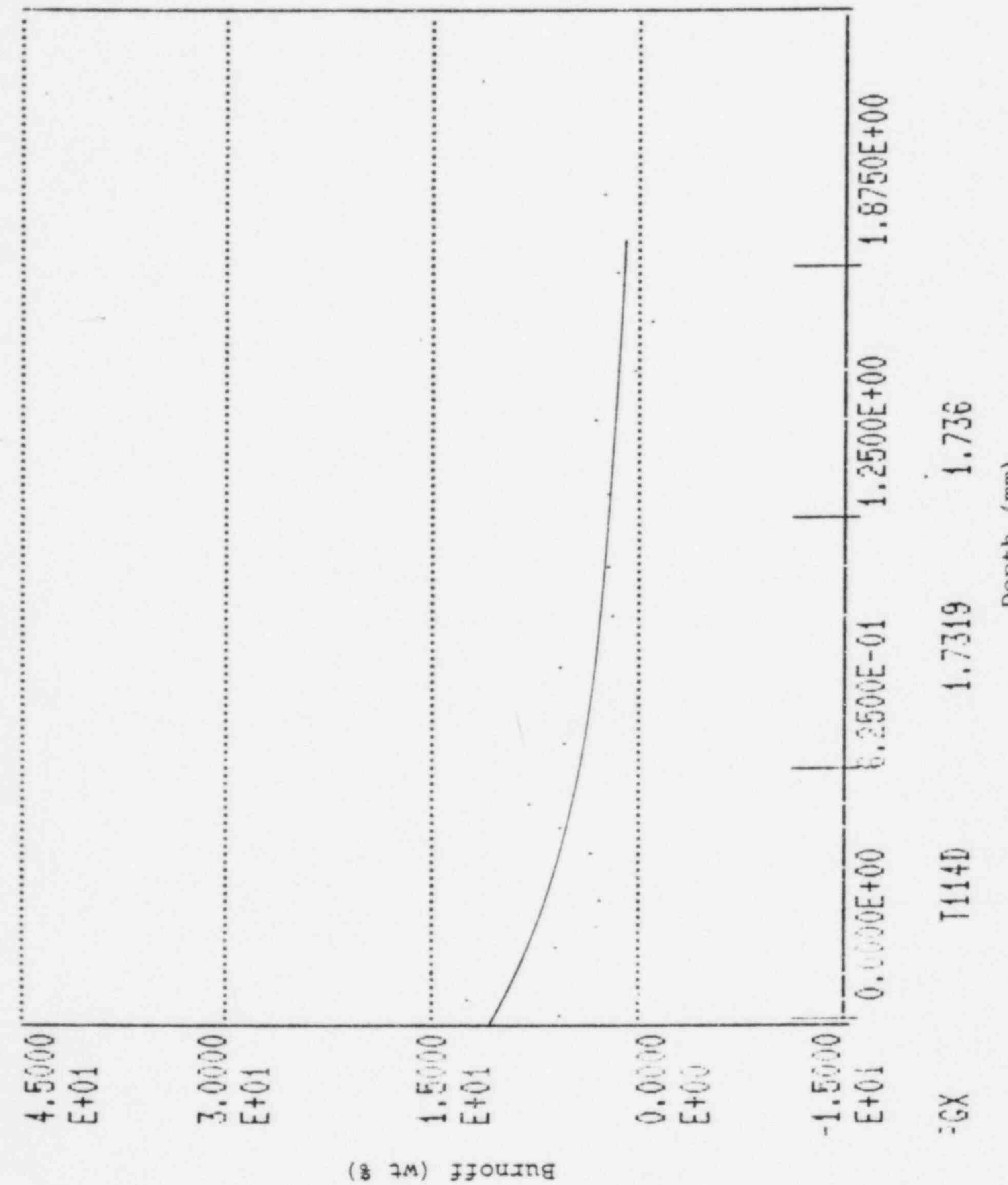

Figure 10(d). Oxidation Profile, Specimen T114D.

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TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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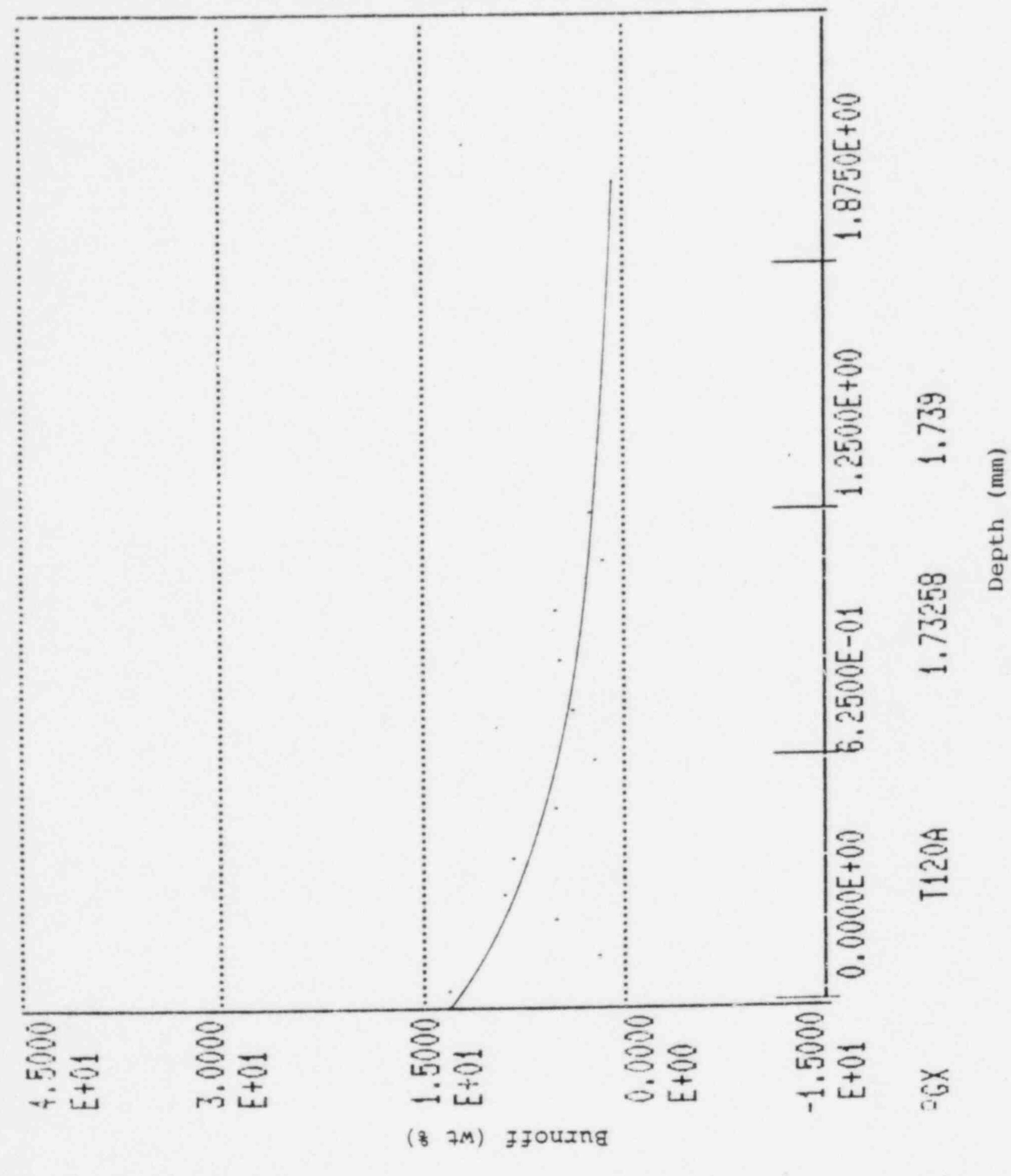

Figure 10(e). Oxidation Profile, Specimen T120A.

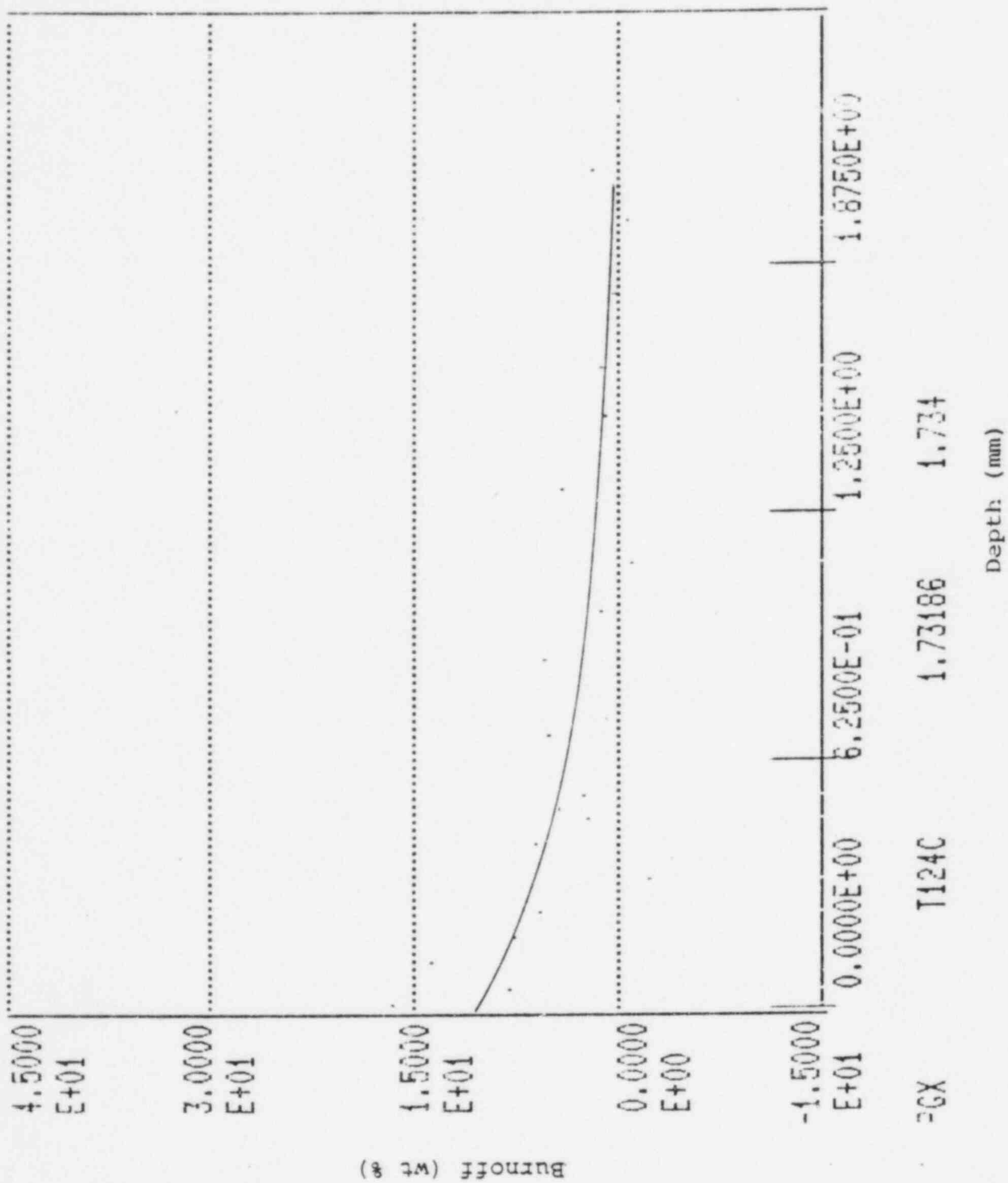

Figure 10(f). Oxidation Profile, Specimen T124C.

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

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Notations in this column indicate where changes have been made

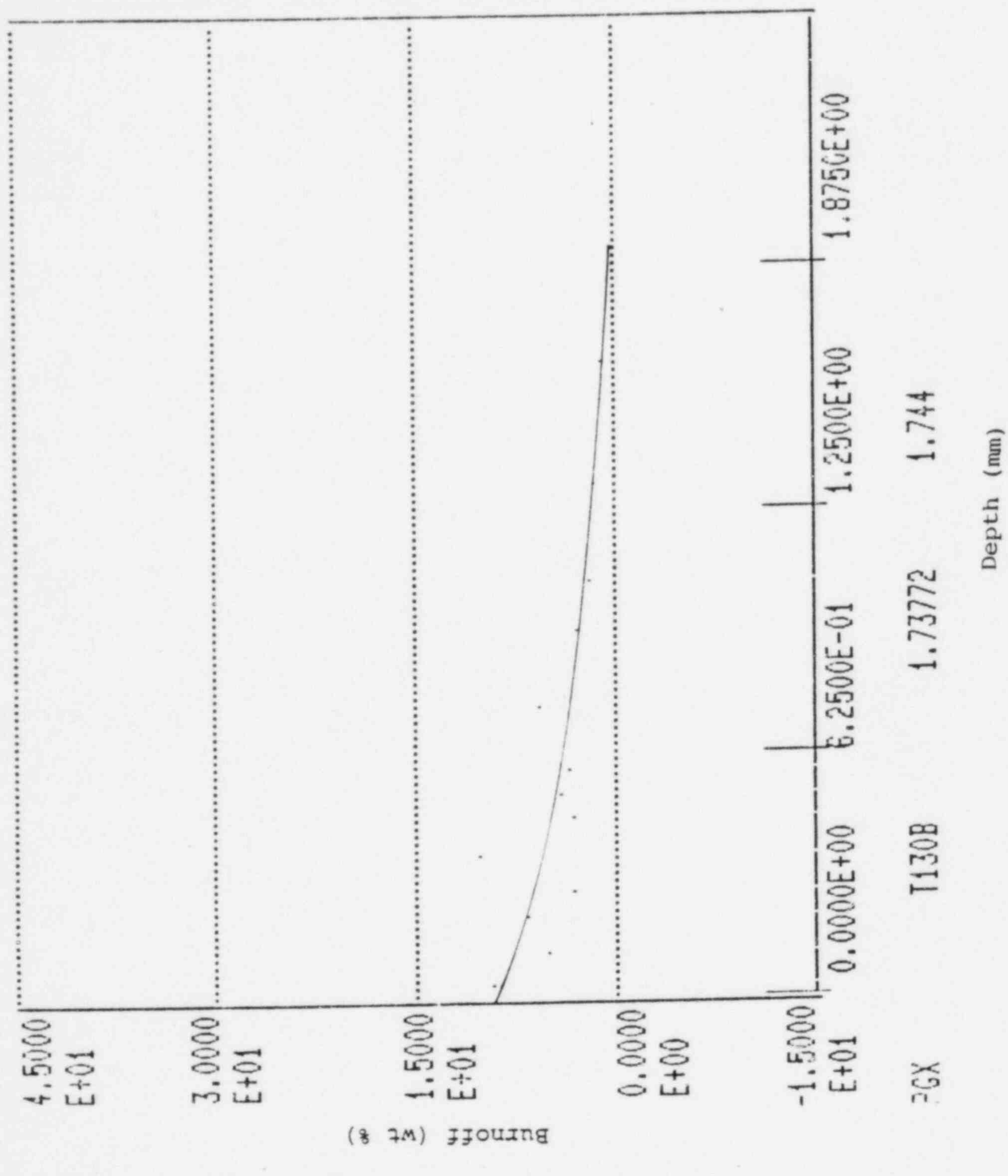


Figure 10(g) Oxidation Profile, Specimen T130B.

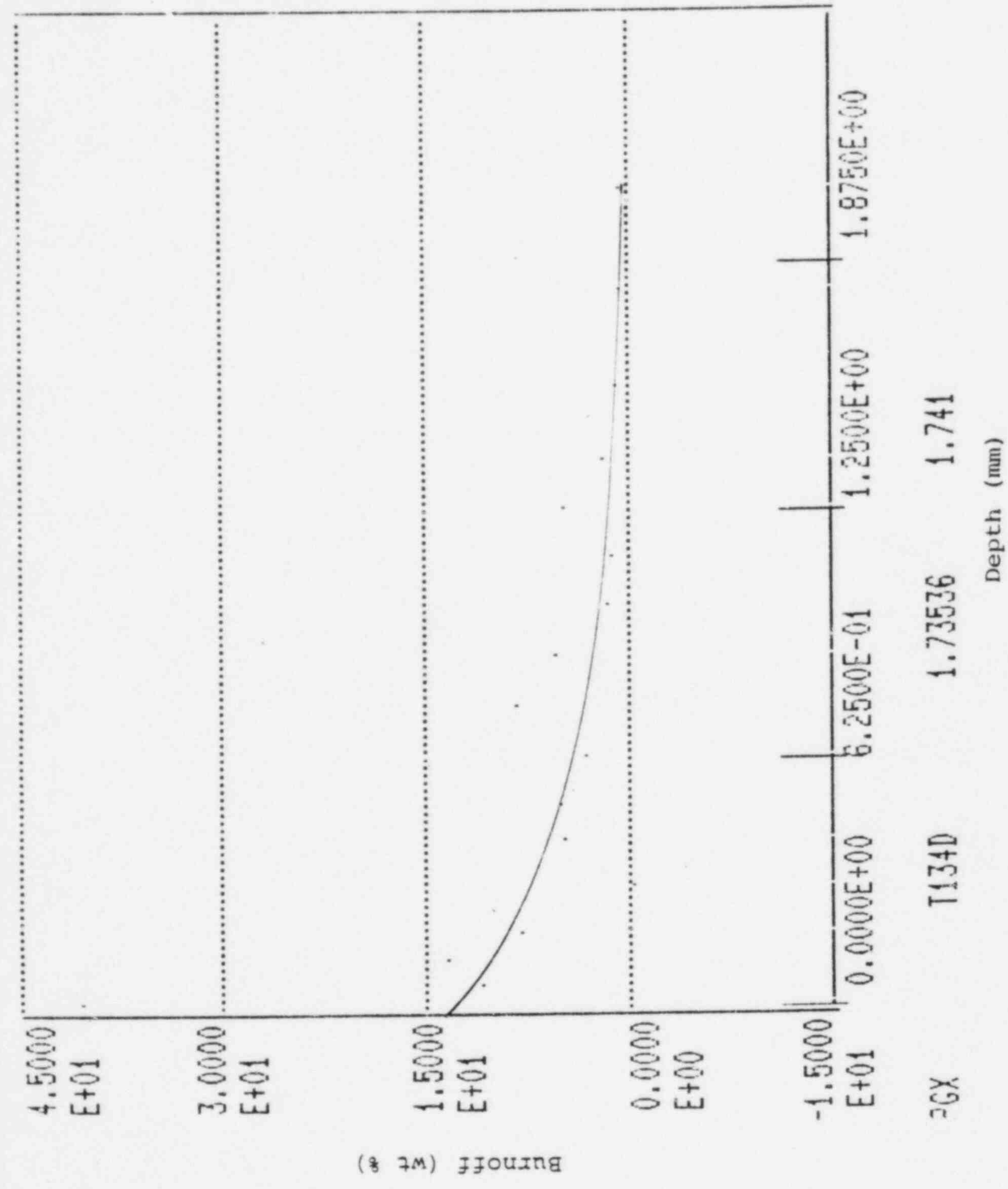
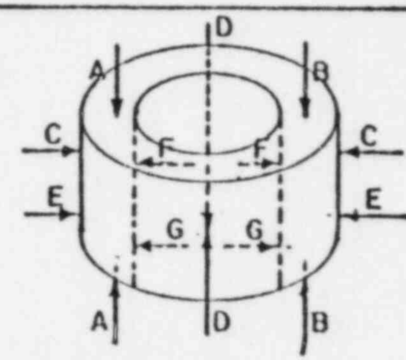


Figure 10(h). Oxidation Profile, Specimen T134D

APPENDIX A

DATE 3/15/82
OPERATOR C.H. Richards/T.M. Gaines
RECORDER L.A. Beavan
QA

REFLECTOR REGION 25



ALL MEASUREMENTS ARE IN INCHES

TARE	SPECIMEN	LENGTH		OUTSIDE DIAMETER			INSIDE DIAMETER		GROSS	APPEARANCE	Net
	NUMBER	A—A	B—B	C—C	D—D	E—E	F—F	G—G	WEIGHT		weight
7.1193	T 100A	.8761	.8755	1.2992	1.2992	1.2992			32.2444	BORE SLIGHTY OX	25.1251
6.7722	T 200A	.8769	.8766	1.2991	1.2991	1.2991			32.3912	BORE OXIDIZED	25.6010
6.9012	T 104C	.8766	.8760	1.2994	1.2994	1.2994			32.0830	BORE SLIGHT OX	25.1818
6.8965	T 204C	.8770	.8768	1.2994	1.2994	1.2994			32.6296	BORE OX	25.7331
7.0718	T 210B	.8766	.8764	1.2994	1.2994	1.2994			32.7814	BORE OX	25.7096
7.0779	T 110B	.8760	.8759	1.2995	1.2995	1.2995			32.3333	SLIGHTLY OX	25.2554
7.1386	T 214D	.8762	.8761	1.2990	1.2989	1.2990			32.8453		25.7067
6.9428	T 114D	.8767	.8766	1.2992	1.2992	1.2992			32.1177		25.1749
6.9004	T 120A	.8760	.8759	1.2991	1.2991	1.2991			32.1056		25.1972
6.8007	T 220A	.8763	.8763	1.2993	1.2993	1.2993			32.4027		25.6020
6.7473	T 124C	.8773	.8778	1.2995	1.2995	1.2995			31.9877		25.2404
6.8625	T 224C	.8762	.8762	1.2993	1.2993	1.2993			32.6039		25.7414
6.7567	T 230B	.8762	.8762	1.2994	1.2994	1.2994			32.5000		25.7433
6.9075	T 130B	.8762	.8761	1.2995	1.2995	1.2995			32.1973		25.2898
6.7726	T 234D	.8751	.8750	1.2990	1.2990	1.2990			32.4383		25.6657
7.0731	T 134D	.8760	.8761	1.2993	1.2993	1.2993			32.3115		25.2384

Figure 1.

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Appendix B.

Figure B-1. Speciemn T100A

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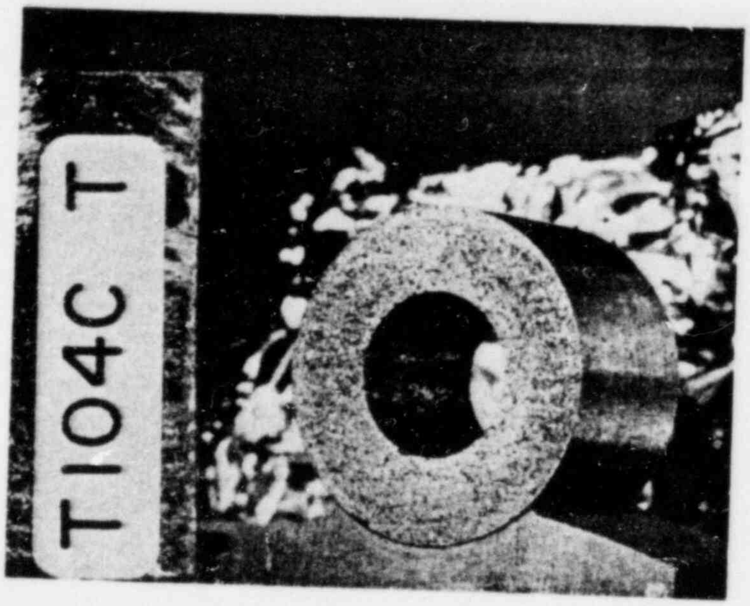

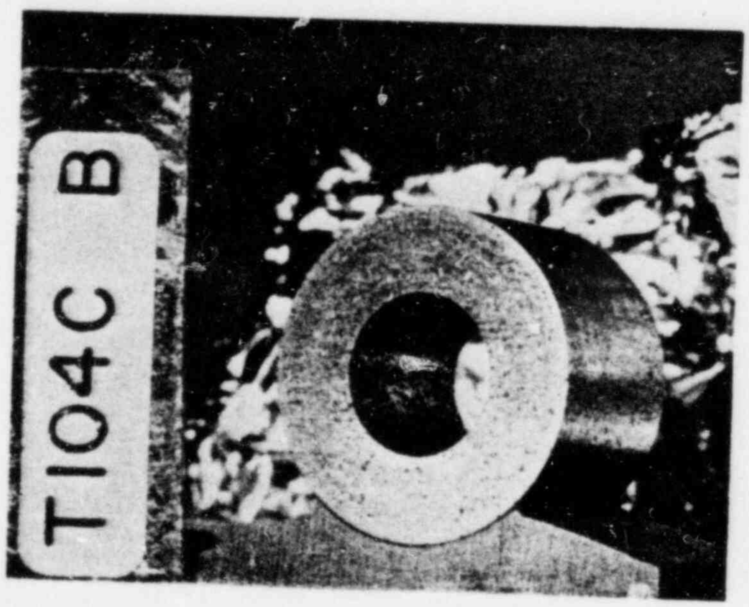

Figure B-2. Specimen T104C

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Appendix B.	Document No. 906624	Issue A

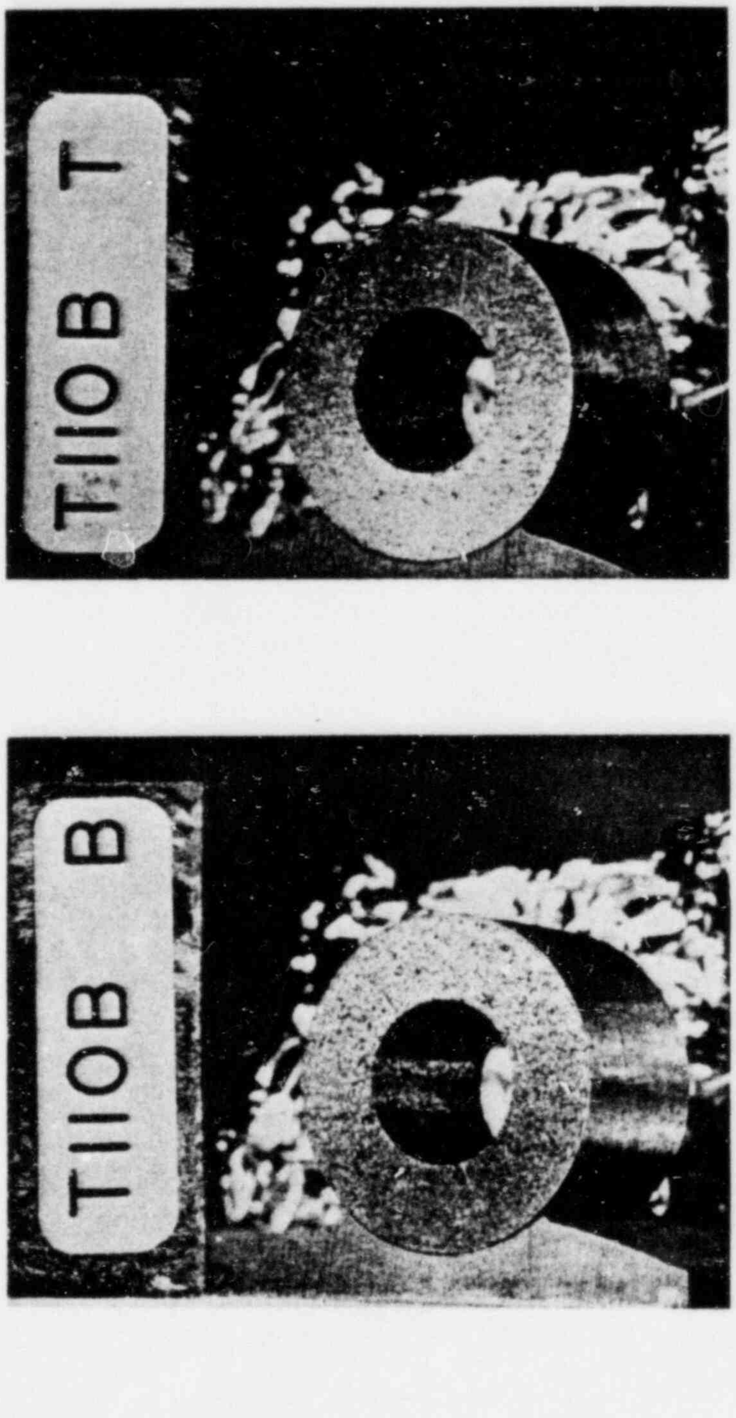

Figure B-3. Specimen T110B

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Appendix B.	Document No. 906624	Issue A

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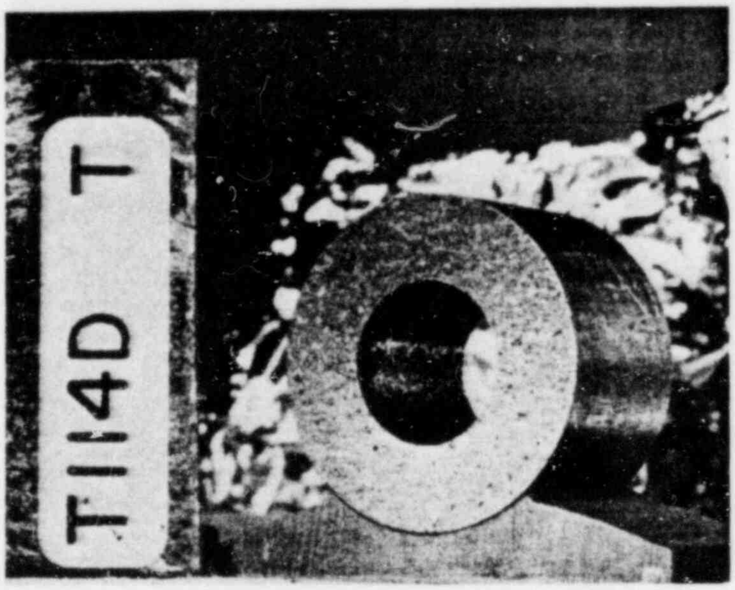


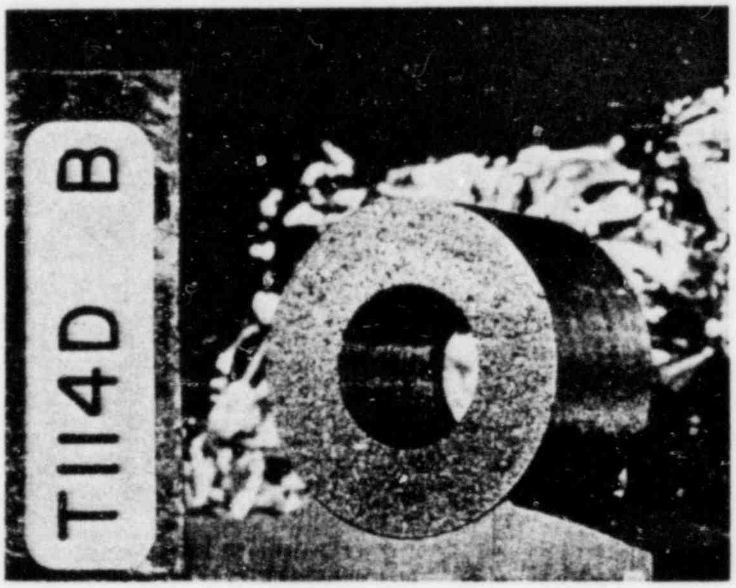


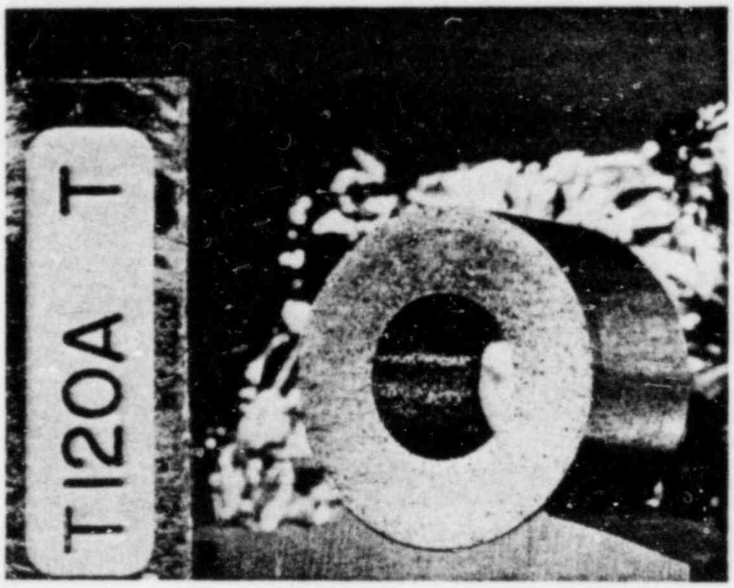
Figure B-4. Specimen T114D

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Appendix B.

Document No. 906624

Issue A



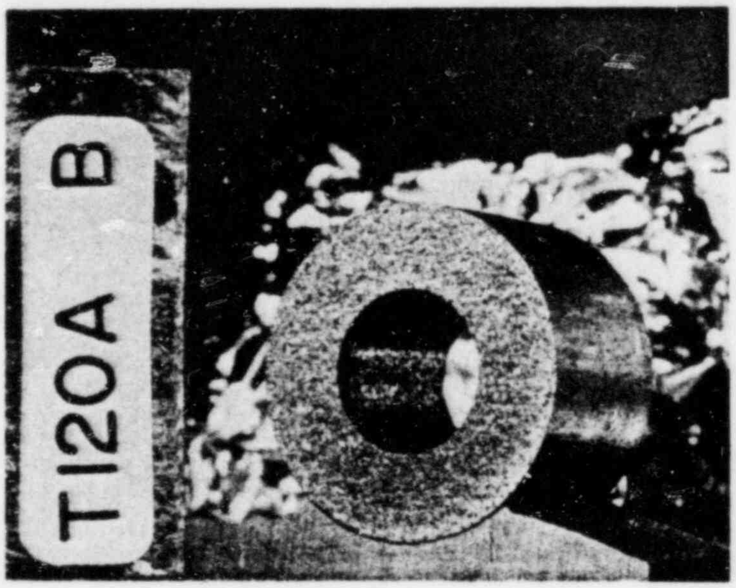


Figure B-5. Specimen T120A

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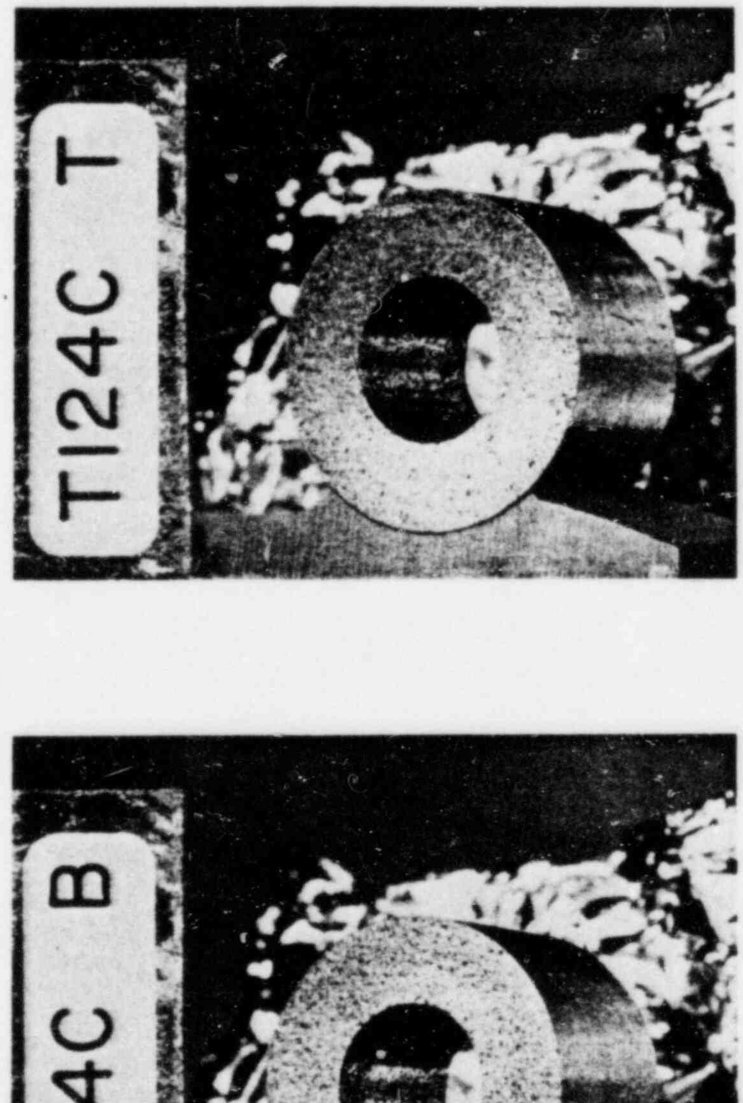

Figure B-6. Specimen T124C

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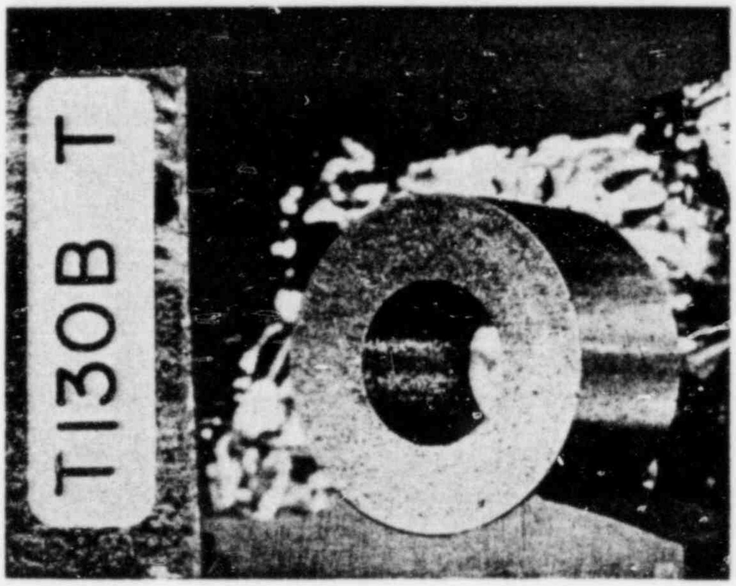

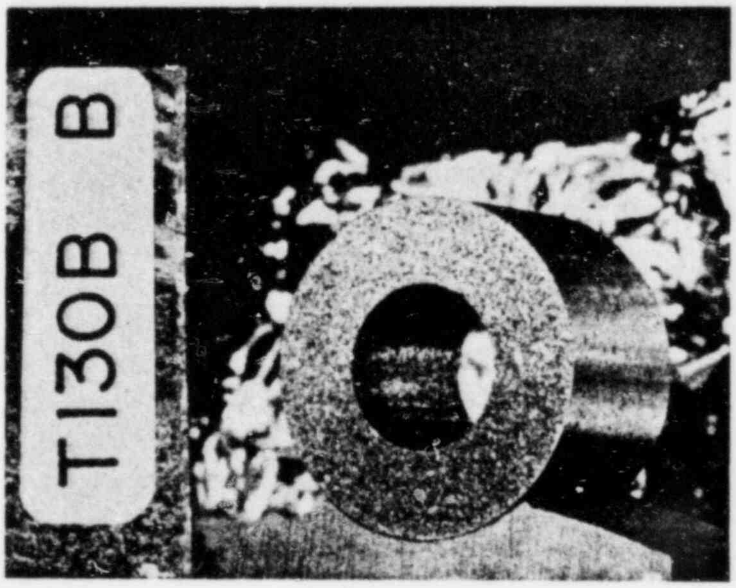

Figure B-7. Specimen T130B

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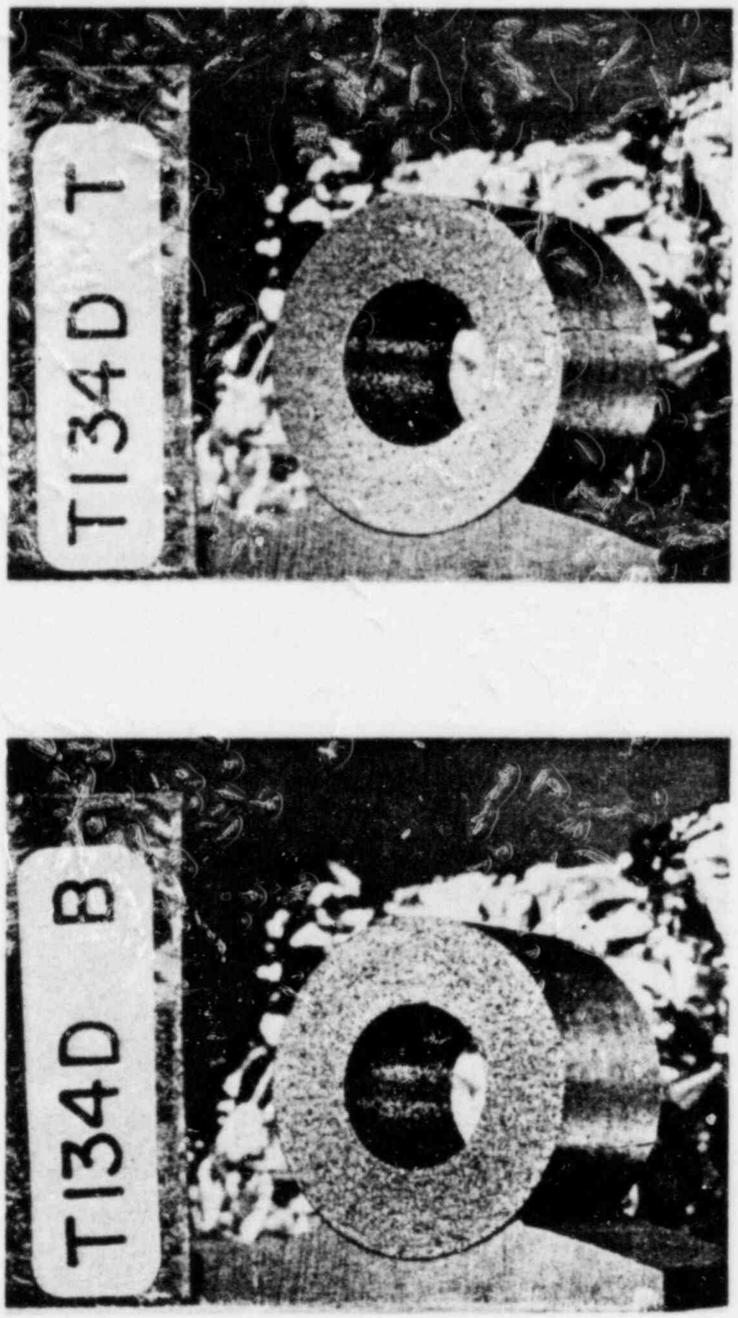

Figure B-8. Specimen T134D

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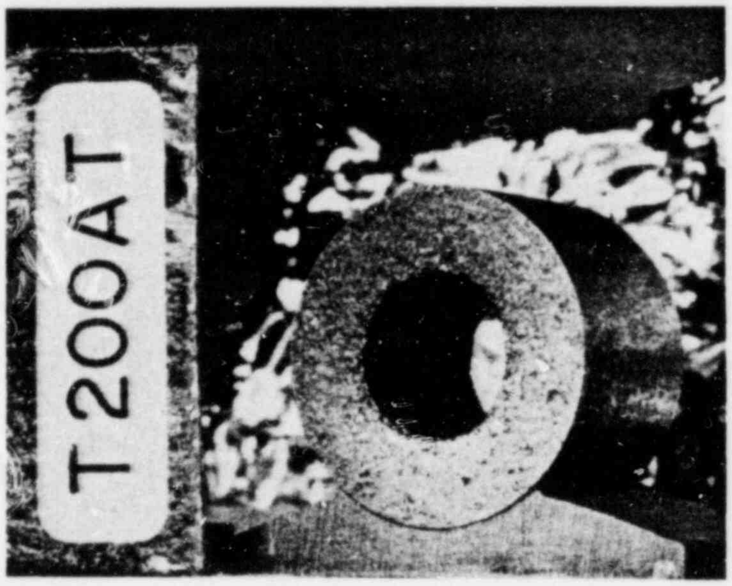

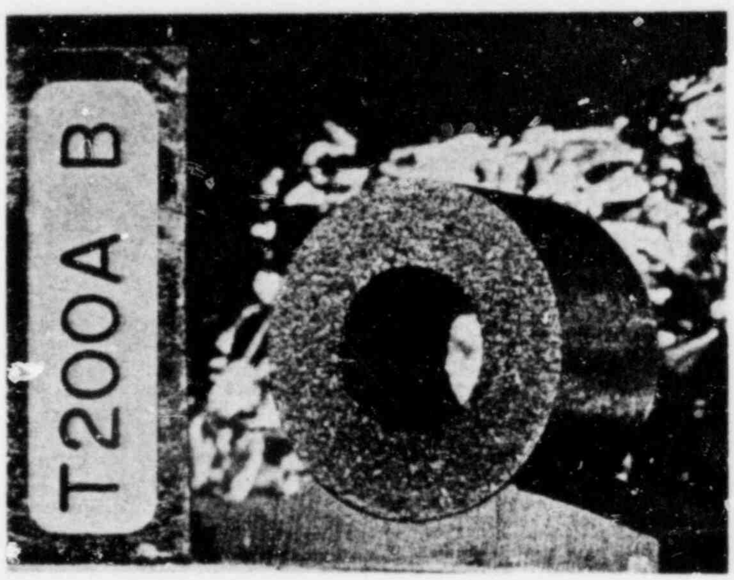

Figure B-9. Specimen T200A

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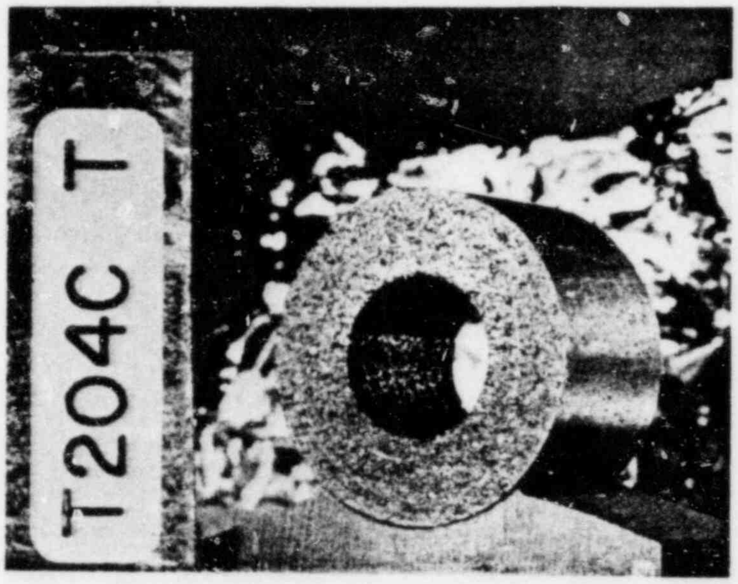

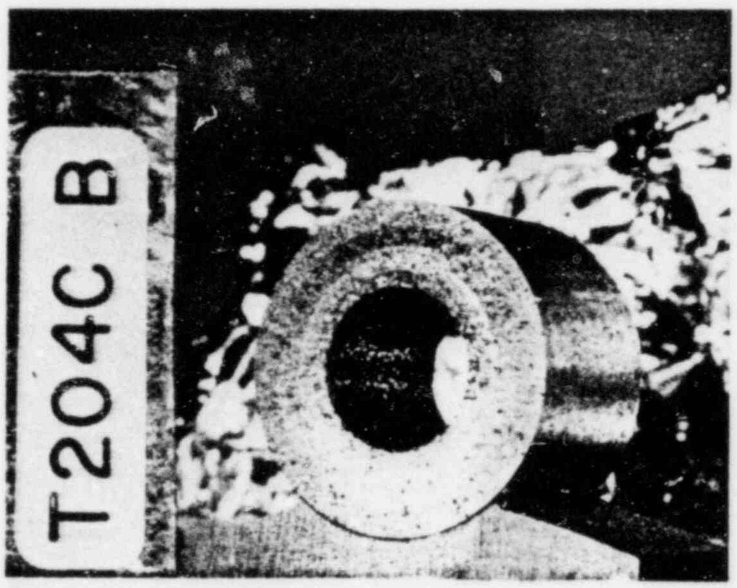

Figure B-10. Specimen T204C

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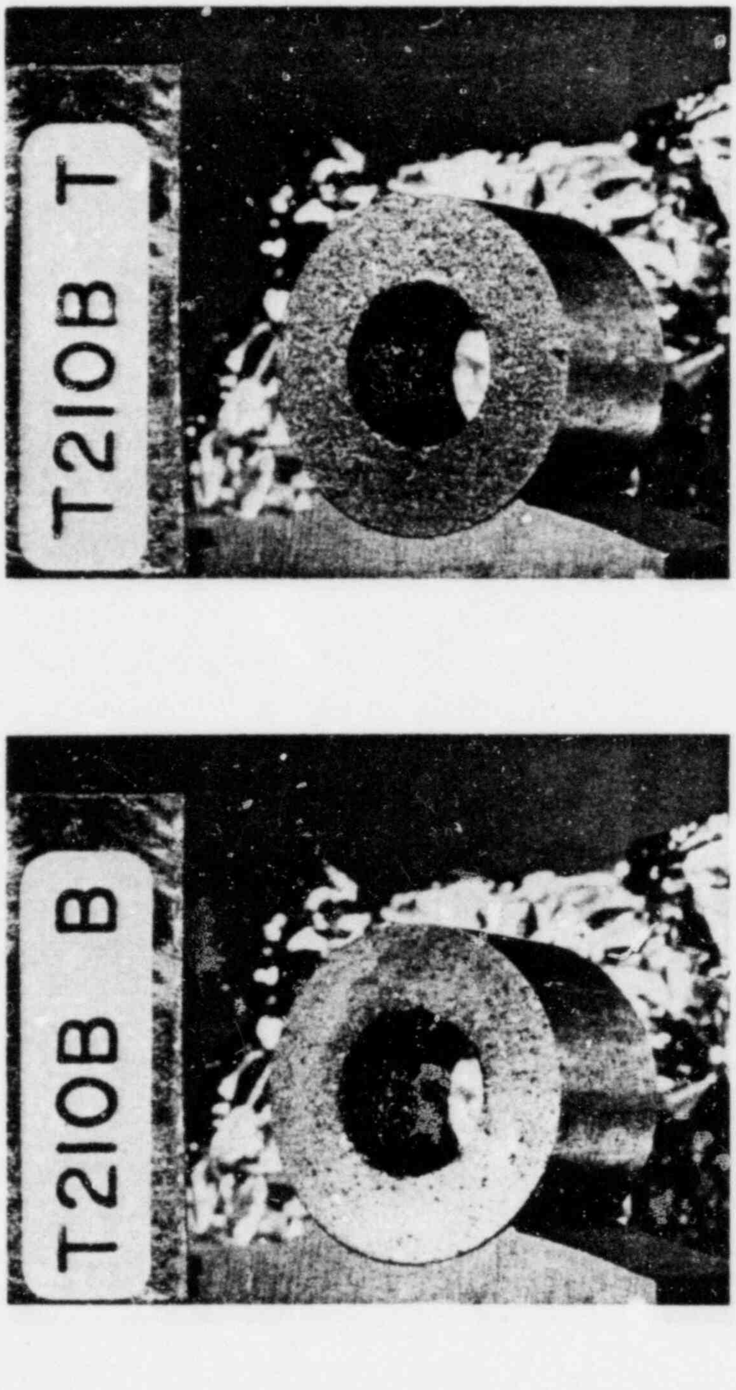

Figure B-11. Specimen T210B

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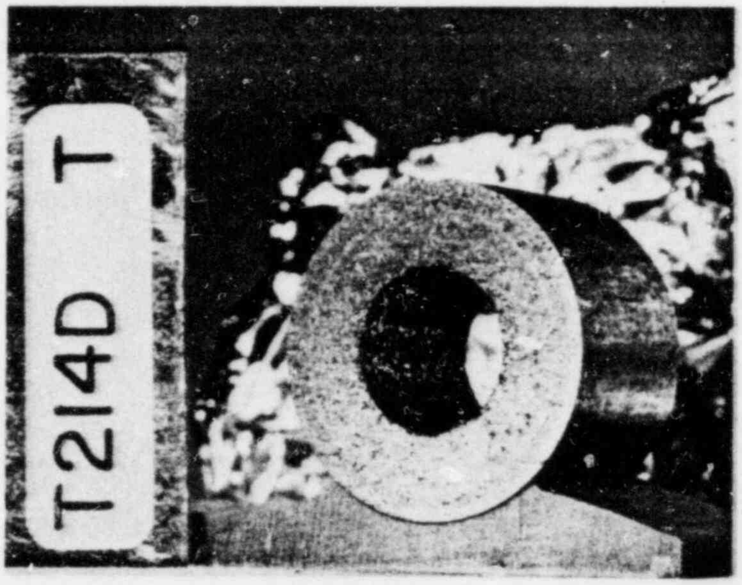
TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No. 906624	Issue A

Appendix B.



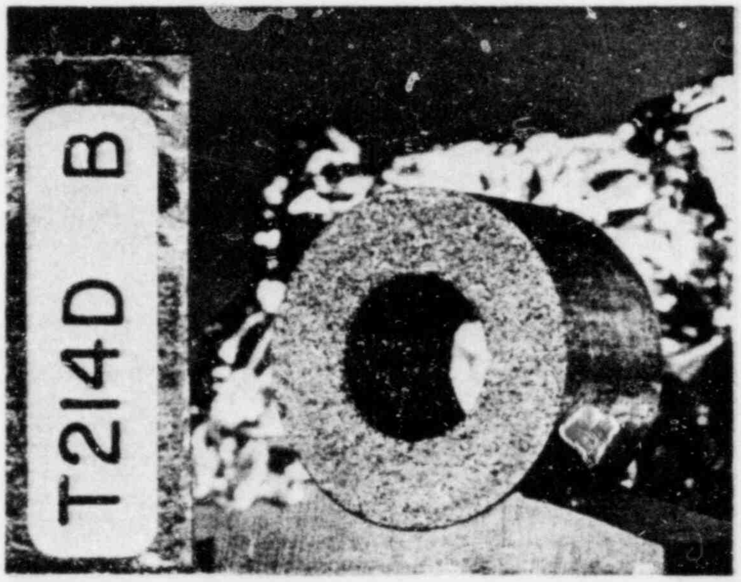
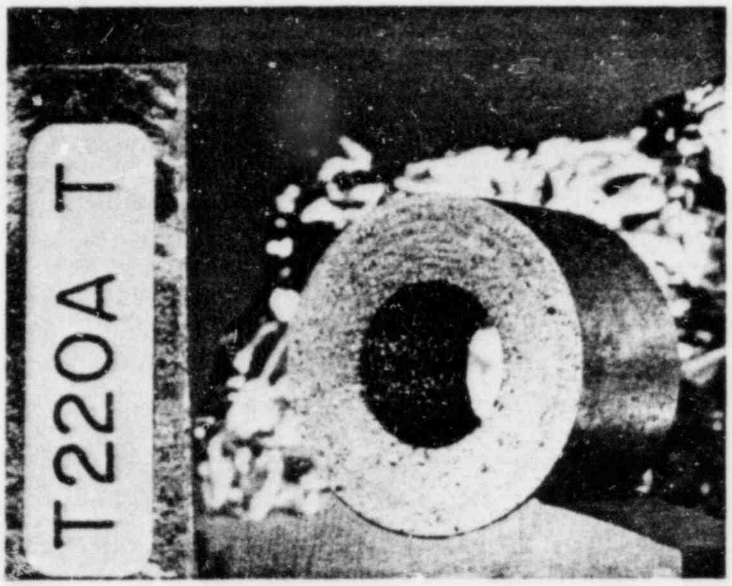


Figure B-12. Specimen T214D

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Appendix B.

Document No. 906624 Issue A



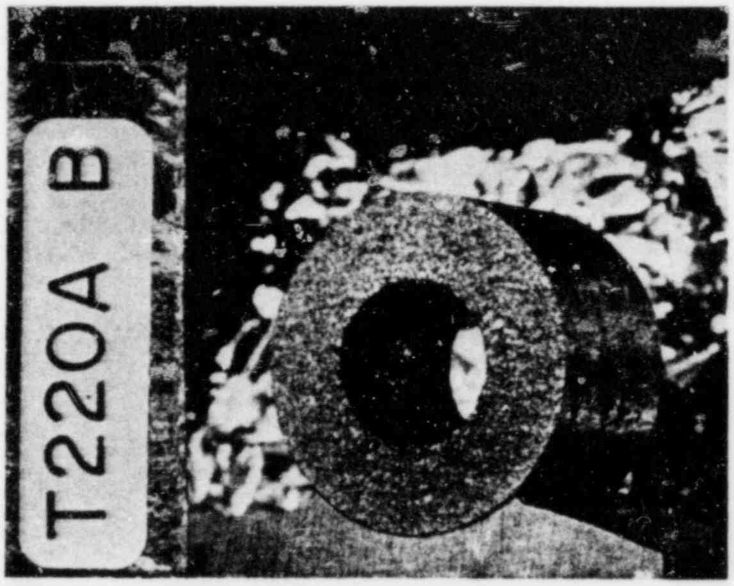


Figure B-13. Specimen T220A

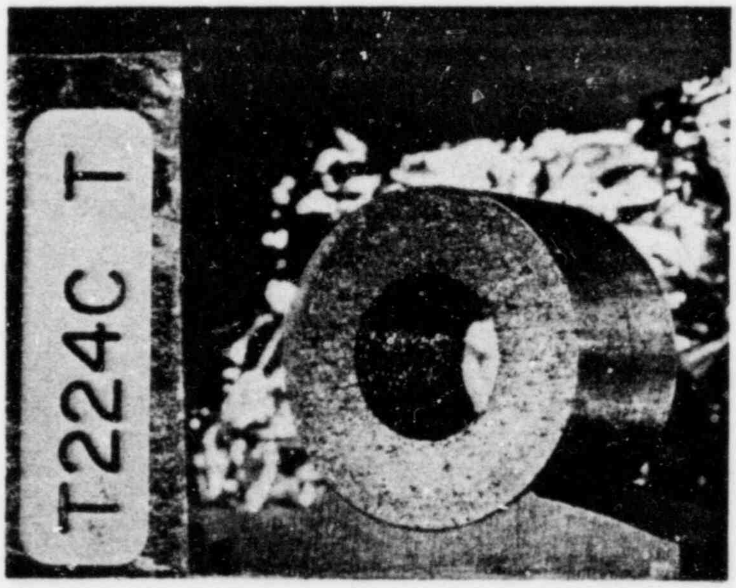
Notations in this column indicate where changes have been made

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Document No. 906624 | Issue A

Appendix B.



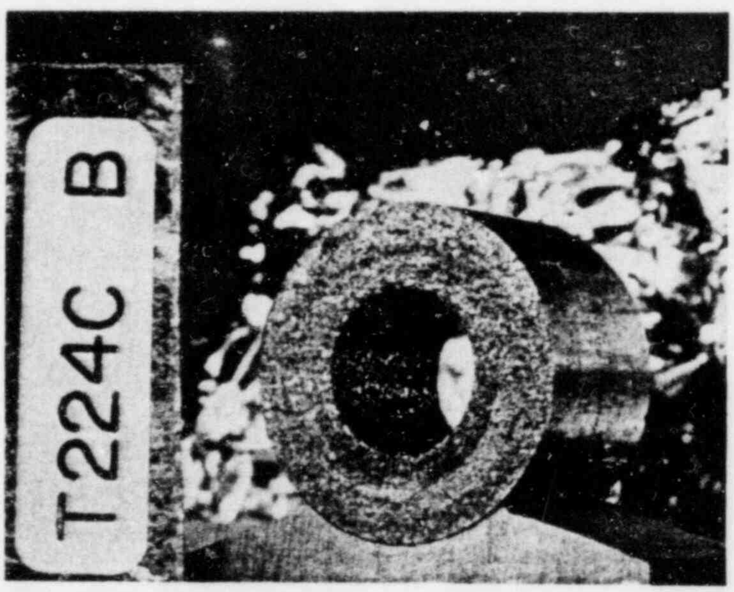


Figure B-14. Specimen T224C

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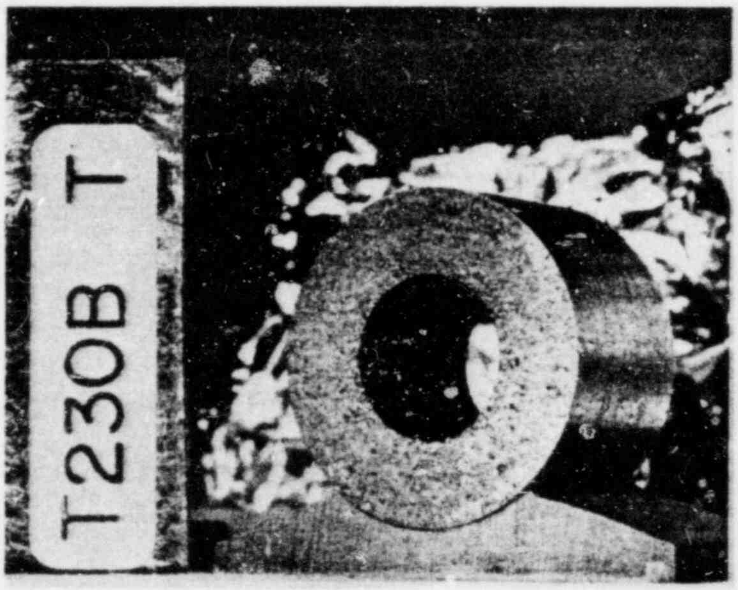

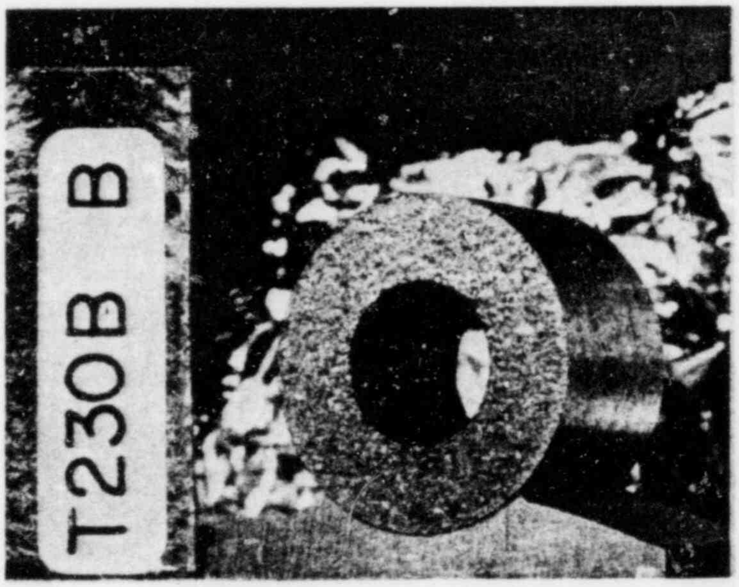

Figure B-15. Specimen T230B

Notations in this column indicate where changes have been made

TITLE: RESULTS OF PGX GRAPHITE SURVEILLANCE
FORT ST VRAIN REGION 25

Appendix B.

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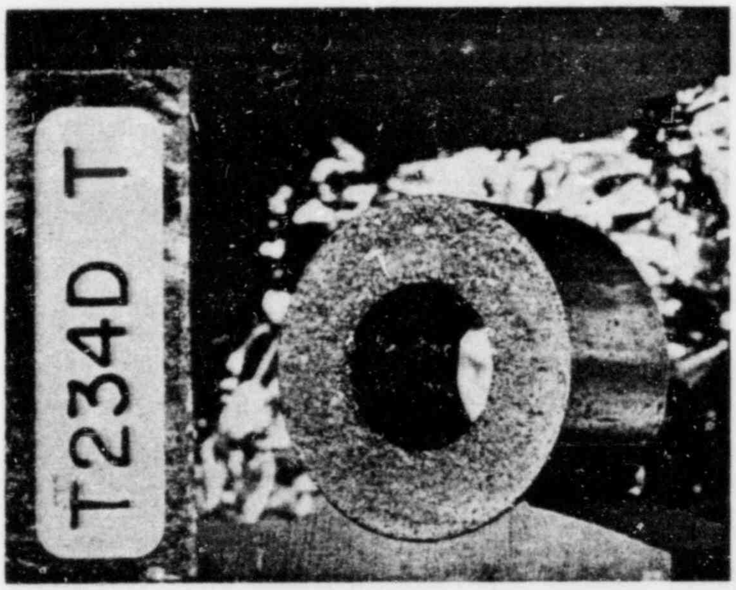

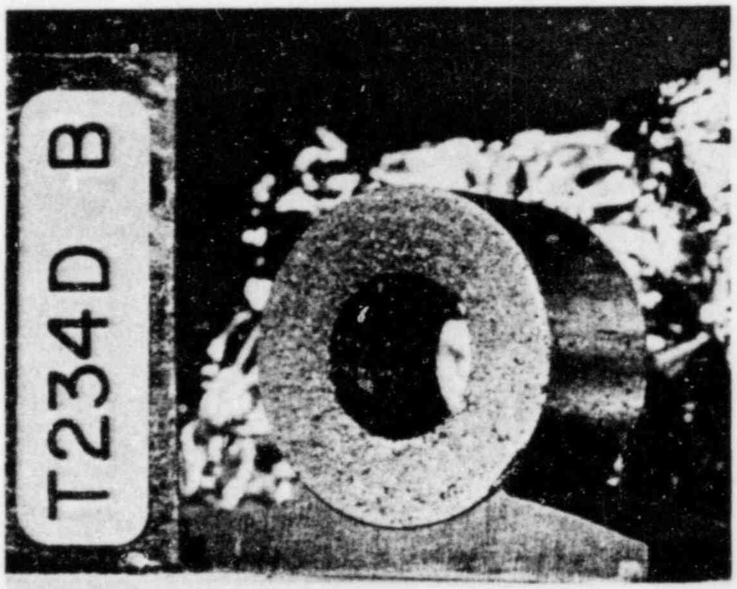

Figure B-16. Specimen T234D