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MASTER

SOLID STATE TRACK RECORDER

MEASUREMENTS IN THE POOLSIDE

CRITICAL ASSEMBLY

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The Poolside Critical Assembly (PCA) Pressure Vessel Benchmark Facility has been fabricated in support of the improvement and validation of the following practices:[1,2]

1. Analysis and Interpretation of Nuclear Reactor Surveillance Results,

2. Surveillance Tests for Nuclear Reactor Vessels,

3. Surveillance Dosimetry Extrapolation,

4. Application of Neutron Transport Methods,

5. Application of Neutron Spectrum Unfolding Methods, and

6. Benchmark Testing of Reactor Vessel Dosimetry.

Figure 1 shows the overall configuration of the facility. The pressure vessel mockup consists of the thermal shield, the pressure vessel simulator, and the void box. Access tubes are provided for easy access of dosimetry instrumentation to critical parts of the configuration. Distances can be easily changed to investigate a variety of different configurations. In an x/y configuration, the number x refers to the distance from the core window to the thermal shield and y to the distance between thermal shield and pressure vessel simulator.

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Fission rate measurements using solid state track recorders (SSTR) have been performed at the PCA. A schematic representation of a cross-section of the PCA is shown in Figure 2. Fission rates were measured in the pressure vessel simulator at the T/4, T/2 and 3T/4 positions and in the void box (VB).[3] SSTR measurements were carried out with ^{232}Th, ^{235}U (bare and cadmium covered), ^{238}U and ^{237}Np fissionable deposits. Midplane only measurements were carried out for ^{235}U and ^{237}Np, while 5 axial locations at 1/4T and 1/2T and 3 axial locations at 3/4T and in the VB were sampled for ^{232}Th and ^{238}U.

The HEDL SSTR fission rate measurements reported herein for both configurations together with NBS and CEN/SCK fission chamber measurements[4] will be used to establish absolute and relative fission reaction rates and ratios for the PCA pressure vessel Benchmark Facility.

These and other fission rate results, then, will be combined with non-fission monitor results[2] to define consistent and reliable sets of accepted integral reaction rate data for benchmark field referencing of (1) reactor physics computations, (2) unfolding code adjustments of input data, (3) individual monitor response characteristics and calibrations, and (4) surveillance capsule calculated perturbation and photo fission correction factors. When combined with the Pool Side Facility (PSF) Metallurgical Pressure Vessel Benchmark Facility high power radiometric and SSTR fission monitor results, the PCA and PSF data will provide confirmation of the applicability of (1) presently recommended fission yield values for key fission products (^{137}Cs, ^{140}Ba, ^{95}Zr, etc.) and (2) Advanced SSTR Dosimetry Capsules, both of which are needed to properly interpret LWR in-and ex-vessel fission monitor results.

EXPERIMENTAL PROCEDURES

Mica SSTR were placed in contact with deposits of the appropriate fissionable materials. For the ^{232}Th and ^{238}U measurements, thick (or asymptotic) sources were used. For ^{235}U, vacuum deposited UF_4 deposits on Al backings were used, and for ^{237}Np, oxide deposits on Ni backings were used. The deposit thickness were 30-55μg/cm^2 ^{235}U on 5 mil Al and 36μg/cm^2 ^{237}Np on 0.5 mil Ni, respectively. The deposit, surrounded by two 3/4" diameter mica SSTR wafers, was placed between two 10 mil cadmium wafers except in the case of the bare ^{235}U measurements, where iron wafers were used in the pressure vessel simulator locations and aluminum wafers were used in the void box. This sandwich was in turn centered in an iron capsule using iron spacers in the pressure vessel simulator positions and in an aluminum capsule using aluminum spacers in the void box position. A cadmium liner was used for the cadmium covered measurements whereas iron or aluminum was used for the ^{235}U bare measurements. Care was taken to avoid cross contamination between deposits when loading or unloading the dosimeters. The exposed mica SSTR were etched for 90 min. in 49.2% HF at 22.7°C and manually scanned using optical microscopy to a statistical accuracy of about 3% (1σ) by at least two independent scanners. For five SSTR, where extremely high track densities were encountered, a scanning electron microscope was used to determine the track densities.

RESULTS AND DISCUSSION

The measured fission rates for ^{232}Th, ^{235}U, ^{238}U, and ^{237}Np are listed in tables 1-4, respectively. The axial distributions of the fission rates for ^{238}U and ^{232}Th are shown in Figures 3-6. In general, some axial dropoff and asymmetry exists in the 1/4T position, whereas the 1/2T, 3/4T, and VB positions are constant to within 25%, 20%, and 7%, respectively. The ^{235}U fission rates of Table II show the extent to which thermal neutrons are absorbed in the PV simulator block. The least thermalized positions are at 1/2T and 3/4T for the 8/7 and 12/13 configurations, respectively. This difference is presumably due to the larger proportion of thermal neutrons incident on the block from the core in the 12/13 configuration coupled with the diminished backshine from the void box in this configuration.

The radial distributions of the isotopic fission rates at mid-plane are shown in Figures 7 and 8. The curves are pseudo-exponential with perturbations caused by the pressure vessel simulator block being most apparent in the case of the ^{235}U fission rates. Overall uncertainties in the reported fission rates are due to individual uncertainties in the exposure time and power level, target mass and uniformity, isotopic abundances, SSTR optical efficiency, statistical errors, and errors associated with microscopic scanning. All of these sources of errors combine in quadrature to yield overall errors in the range from 2.5 - 3% for ^{235}U, ^{238}U and ^{232}Th. The ^{237}Np targets were uniform to only 3% leading to an overall deviation of 4.2% for the ^{237}Np fission rates. The ^{238}U fission rates for the T/4 location in the 8/7 configuration have an overall standard deviation of about 12% due to some special problems encountered with high track densities in these exposures.

ACKNOWLEDGEMENTS

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2. W. N. McElroy, R. Gold, G. L. Guthrie, L. S. Kellogg, E. P. Lippincott, J. A. Grundl, C. M. Eisenhauer, E. D. McGarry, F. B. K. Kam, L. F. Miller, F. W. Stallmann, C. Z. Serpan, A. Fabry, J. Debrue, G. DeLeeuw, G. Minsart, H. Tourwe, D. Pachur, W. Schneider, L. Weise, M. Austin, P. Burch, G. R. Odette, R. A. Wullaert, and S. L. Anderson, "Development and Testing of Standardized Procedures and Reference Data for LWR Surveillance", IAEA Specialists' Meeting on "Irradiation Embrittlement, Thermal Annealing, and Surveillance of Reactor Pressure Vessels", Feb. 26-March 1, 1979, Vienna, Austria.

3. The T/4, T/2, and 3T/4 designations represent distances from the front face of the PV simulator whose total thickness is T.

4. E. D. McGarry, A. Fabry, "Measurements of Spectral Indices and Fission and Activation Rates in a Light Water Reactor." Proceedings of the Third ASTM-EURATOM Symposium, Ispra, 1979.

TABLE I PCA ^{232}Th FISSION RATES

CONFIGURATION	POSITION	T/4	T/2	3T/4	V.B.
		Fissions/Atom/(kw-hr) x 10^{16}			
8/7	+150	44.22 ± 1.28	19.53 ± 0.57	-	-
	+ 75	52.23 ± 1.44	23.64 ± 0.68	9.184 ± 0.266	2.369 ± 0.075
	0	56.97 ± 1.65	24.59 ± 0.71	9.963 ± 0.28	2.717 ± 0.079
	- 75	55.59 ± 1.53	23.81 ± 0.69	9.150 ± 0.265	2.650 ± 0.077
	-130	57.03 ± 1.81	22.46 ± 0.65	-	-
12/13	+150	9.252 ± 0.246	3.829 ± 0.121	-	-
	+ 75	10.63 ± 0.29	4.222 ± 0.122	-	0.4599 ± 0.0126
	0	11.63 ± 0.32	4.809 ± 0.153	1.970 ± 0.054	0.5048 ± 0.0139
	- 75	11.55 ± 0.32	4.552 ± 0.144	1.923 ± 0.053	0.4984 ± 0.0137
	-130	9.802 ± 0.27	4.342 ± 0.125	-	-

TABLE II PCA ^{235}U FISSION RATES

CONFIGURATION		Location[a] T/4	T/2	3/4T	V.B.
		Fissions/Atom/(kw-hr) x 10^{14}			
8/7	Bare	633.1 ± 19.1	178.8 ± 5.4	90.98 ± 2.73	-
	Cd-Covered	337.0 ± 10.2	164.2 ± 4.9	75.08 ± 2.25	26.65
	Ratio	1.879 ± 0.079	1.089 ± 0.046	1.212 ± 0.051	-
12/13	Bare	-	23.96 ± 0.72	11.86 ± 0.35	4.826 ± 0.145
	Cd-Covered	37.19 ± 1.12	19.08 ± 0.57	10.95 ± 0.33	3.605 ± 0.108
	Ratio	-	1.256 ± 0.053	1.083 ± 0.045	1.339 ± 0.056

[a] Mid-plane only.

TABLE III PCA ^{238}U FISSION RATES

CONFIGURATION	POSITION	T/4	T/2	3T/4	V.B.
		Fissions/Atom/kw-hr x 10^{16}			
8/7	+150	135 ± 32	74.57 ± 2.24	-	-
	+ 75	327 ± 39	87.48 ± 2.62	39.75 ± 1.19	9.080 ± 0.272
	0	331 ± 40	85.14 ± 2.55	42.75 ± 1.28	8.962 ± 0.269
	- 75	360 ± 44	108.6 ± 3.2	36.21 ± 1.09	8.917 ± 0.267
	-130	227 ± 27	69.79 ± 2.1	-	-
12/13	+150	32.62 ± 0.98	15.20 ± 0.46	-	-
	+ 75	32.33 ± 0.97	13.70 ± 0.41	5.589 ± 0.168	1.928 ± 0.058
	0	37.85 ± 1.14	17.41 ± 0.52	7.824 ± 0.235	1.777 ± 0.053
	- 75	39.09 ± 1.18	17.78 ± 0.53	7.628 ± 0.228	1.557 ± 0.046
	-130	31.25 ± 0.94	17.19 ± 0.51	-	-

TABLE IV PCA ^{237}Np FISSION RATES

CONFIGURATION	Location [a] T/4	T/2	3T/4	V.B.
	Fissions/Atom(kw-hr) x 10^{14}			
8/7	18.23 ± 0.77	10.21 ± 0.43	5.090 ± 0.214	-
12/13	3.361 ± 0.141	1.812 ± 0.076	1.040 ± 0.044	-

a/ Midplane only.

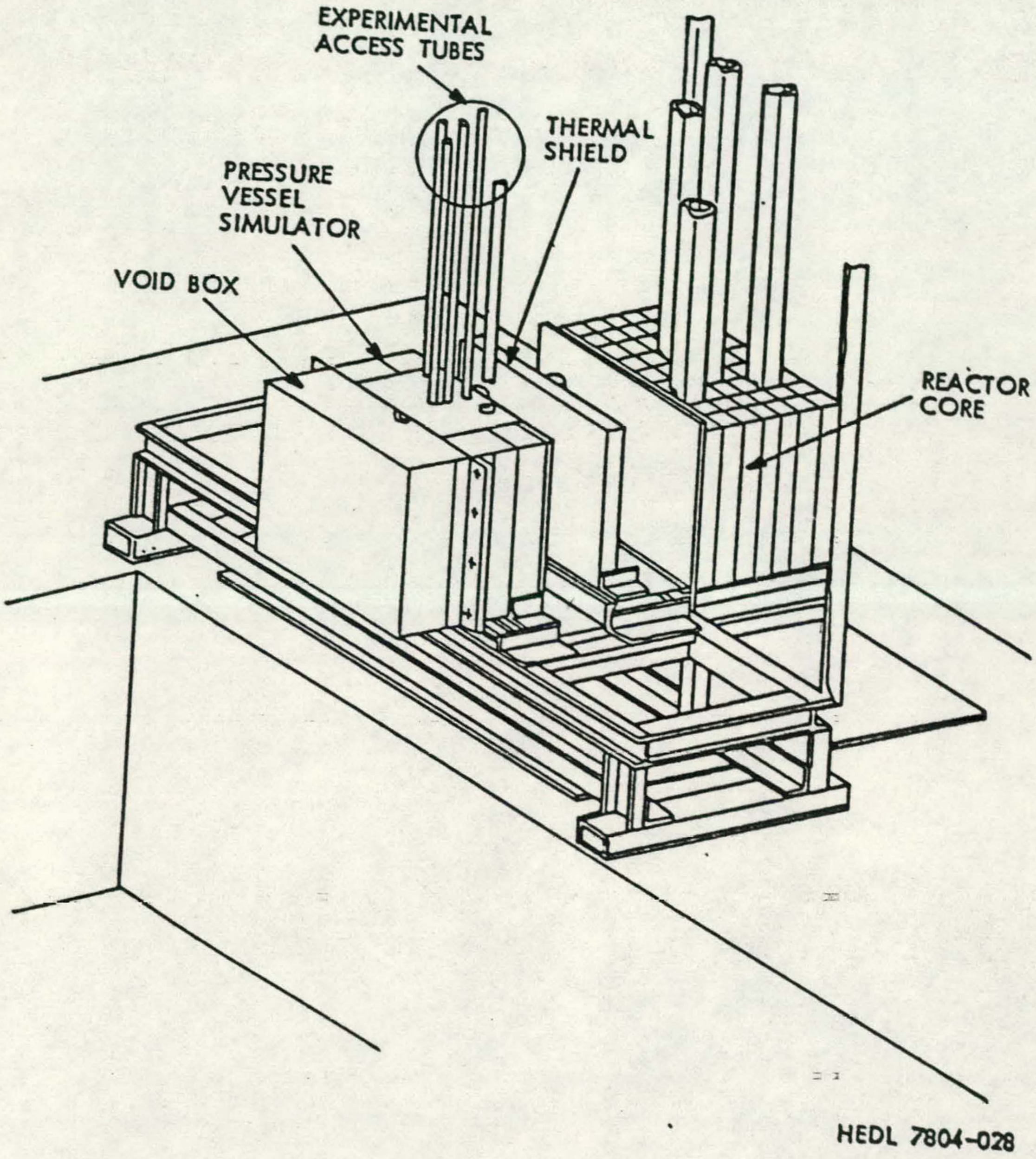
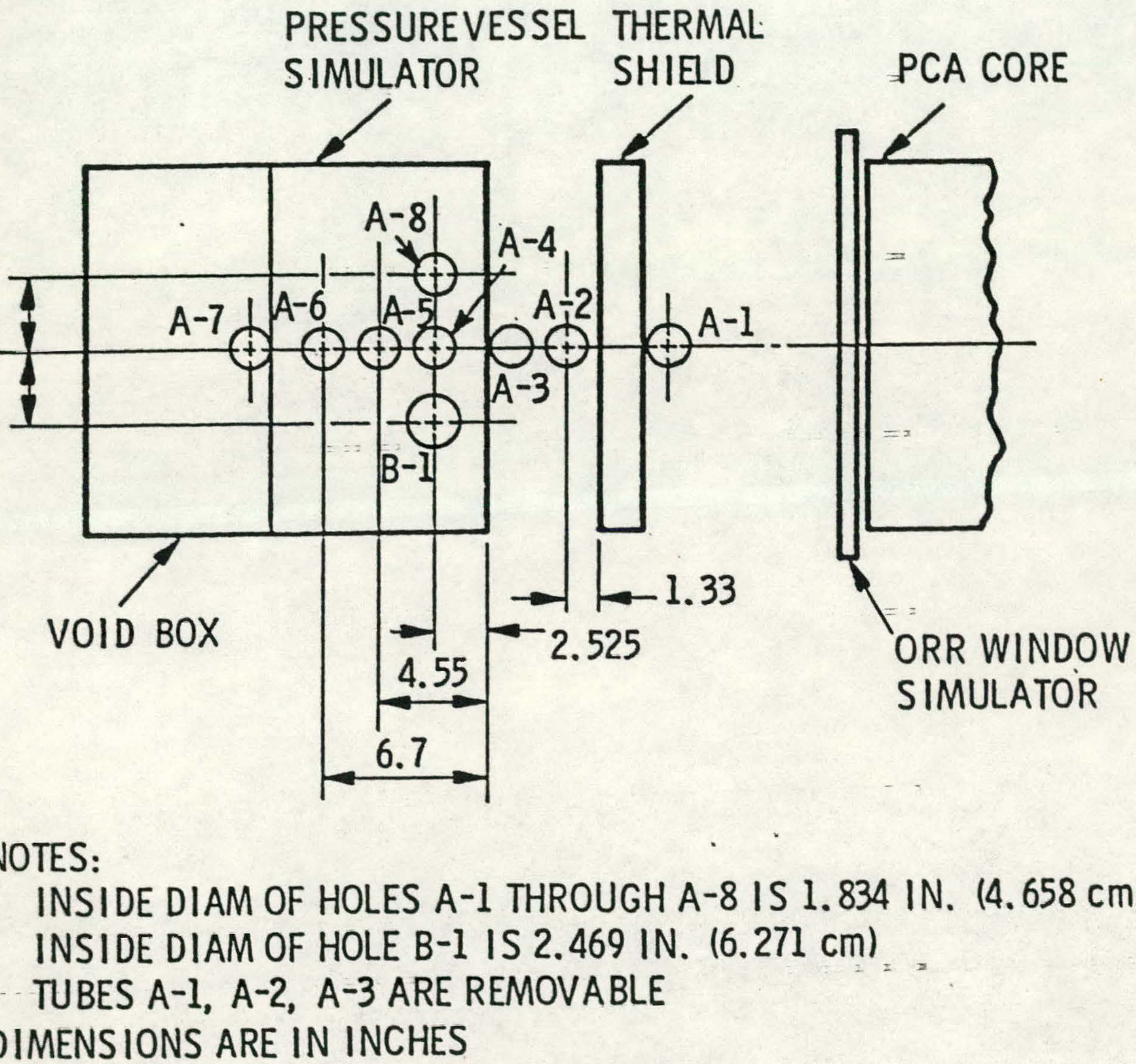


FIGURE ~~15~~ 1. Pressure Vessel Wall Mock-up Schematic of Two Equivalent Facilities Under Construction at ORNL. The high-flux version at ORR (PSF) will include damage exposure of metallurgical test specimens; the low-flux version near a low-power critical assembly (PCA) will focus on active and passive dosimetry measurements.



NOTES:

INSIDE DIAM OF HOLES A-1 THROUGH A-8 IS 1.834 IN. (4.658 cm)
INSIDE DIAM OF HOLE B-1 IS 2.469 IN. (6.271 cm)
TUBES A-1, A-2, A-3 ARE REMOVABLE

DIMENSIONS ARE IN INCHES

FIGURE 2. Experimental Configuration for Dosimetry Measurements at PCA.

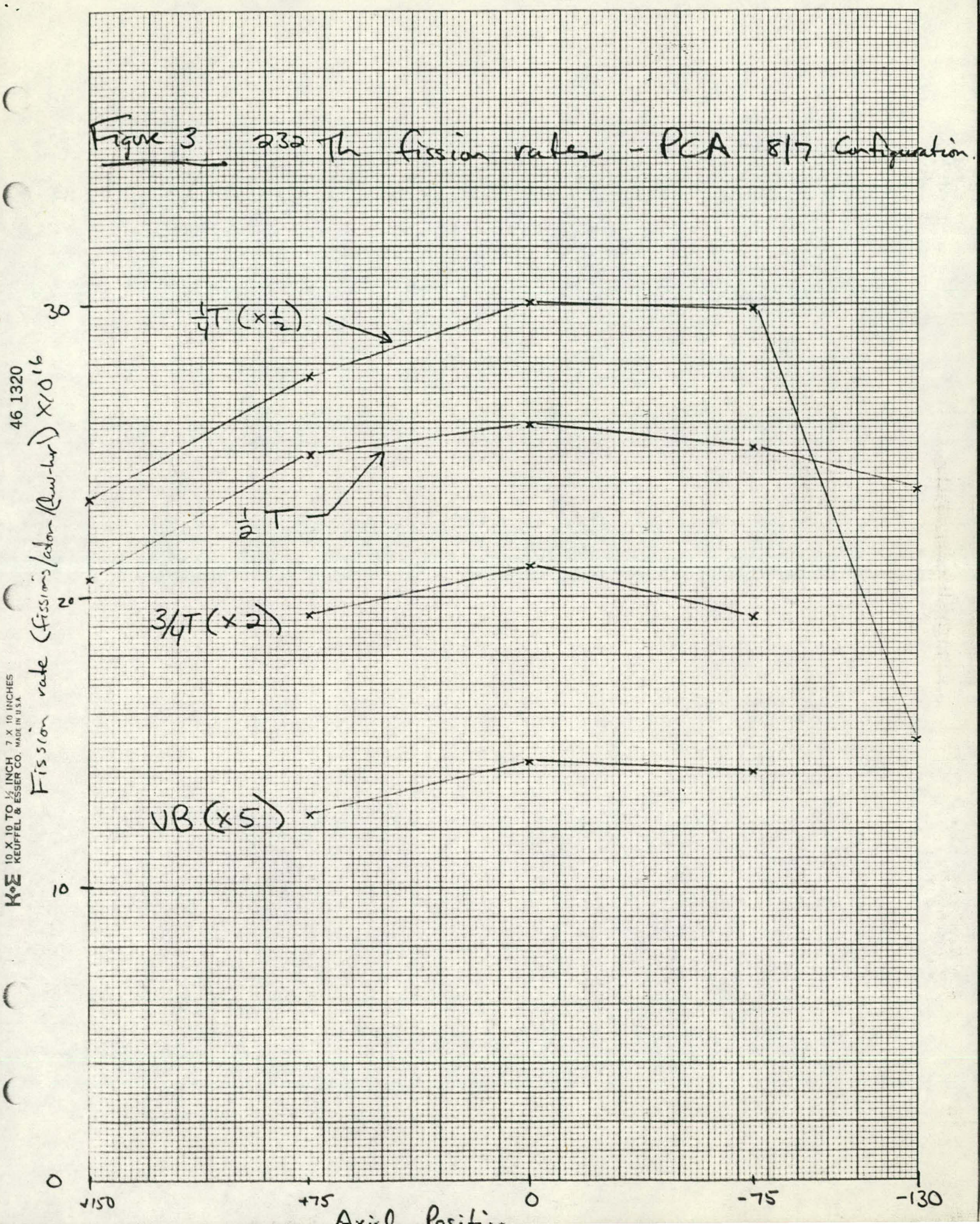


Figure 3 232Th fission rates - PCA 8/7 Configuration.

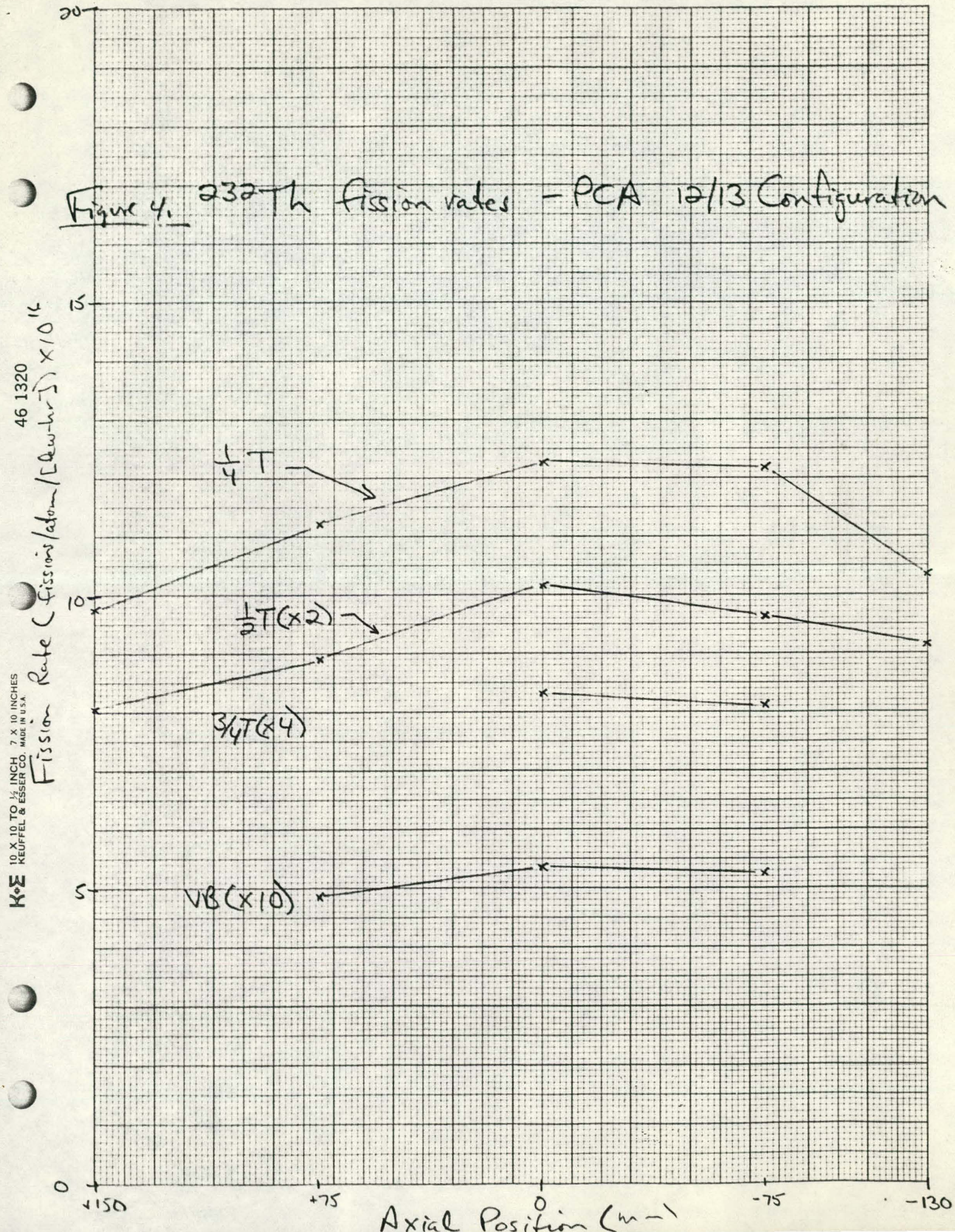


Figure 4. 232Th fission rates - PCA 12/13 Configuration
Fission Rate (fissions/atom/[kw-hr]) ×10^14
20
15
10
5
0
1/4 T
1/2 T(x2)
3/4 T(x4)
VB(x10)
+150
+75
0
-75
-130
Axial Position (mm)
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

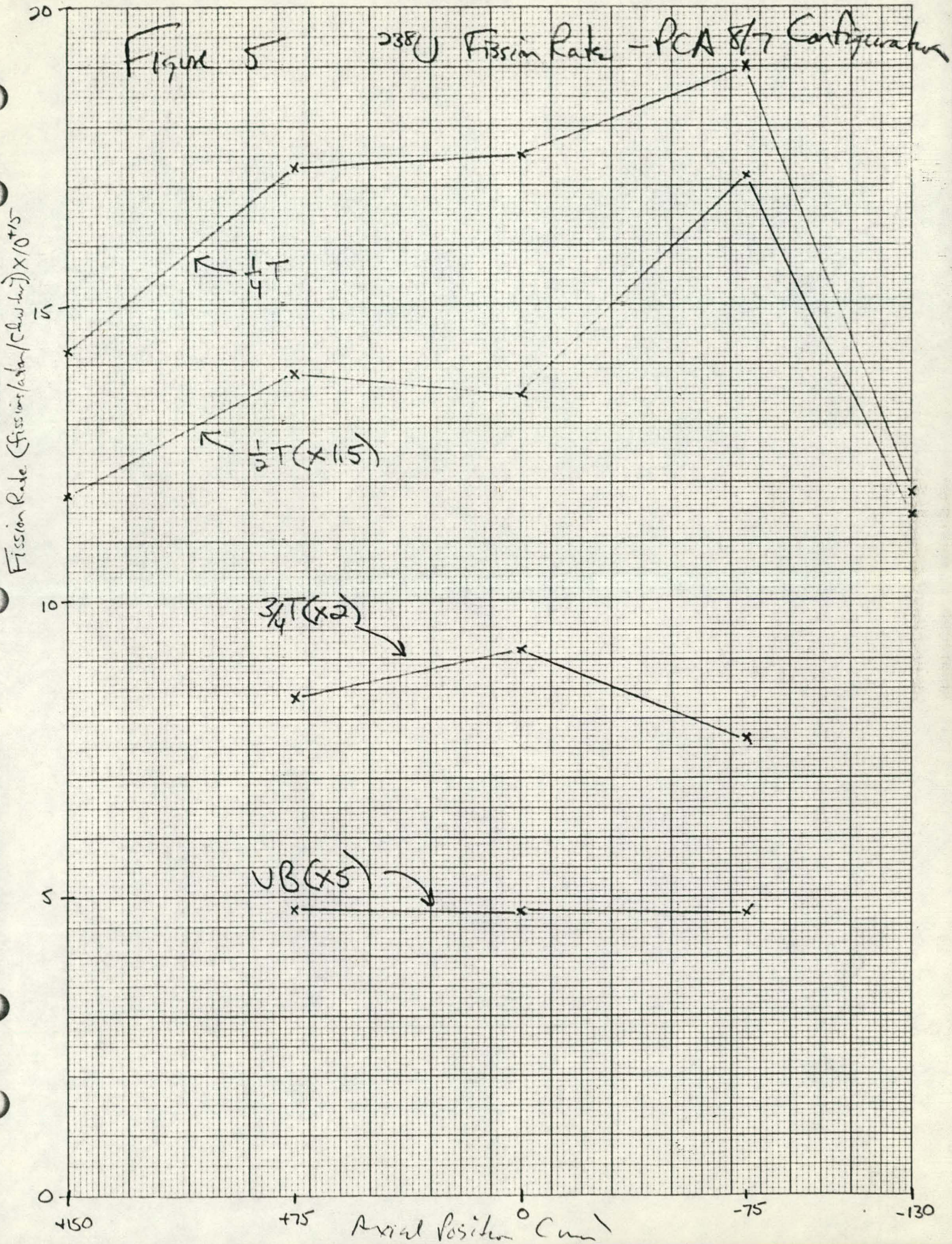


Figure 5
238U Fission Rate - PCA 8/7 Configuration
Fission Rate (fissions/atom/(class hr)) x10^+15
Axial Position (cm)
20
15
10
5
0
+150
+75
0
-75
-130
1/4 T
1/2 T (x 1.5)
3/4 T (x2)
VB (x5)

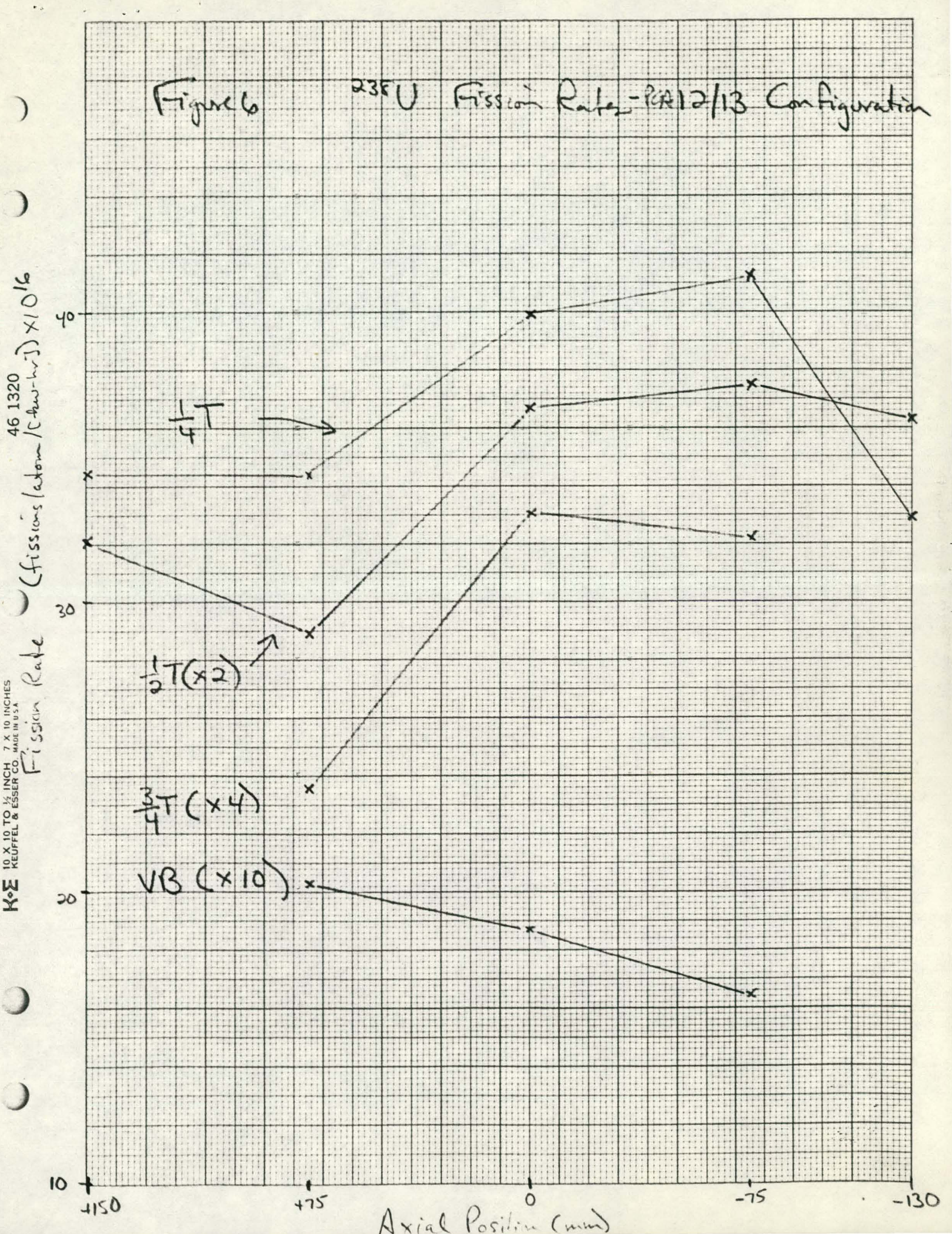


Figure 6 235U Fission Rate - PCA 12/13 Configuration
Fission Rate (fissions/atom/[thw-hr]) x10^16
40
30
20
10
1/4 T
1/2 T (x2)
3/4 T (x4)
VB (x10)
+150
+75
0
-75
-130
Axial Position (mm)
K&E 10 X 10 TO 1/2 INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN USA 46 1320

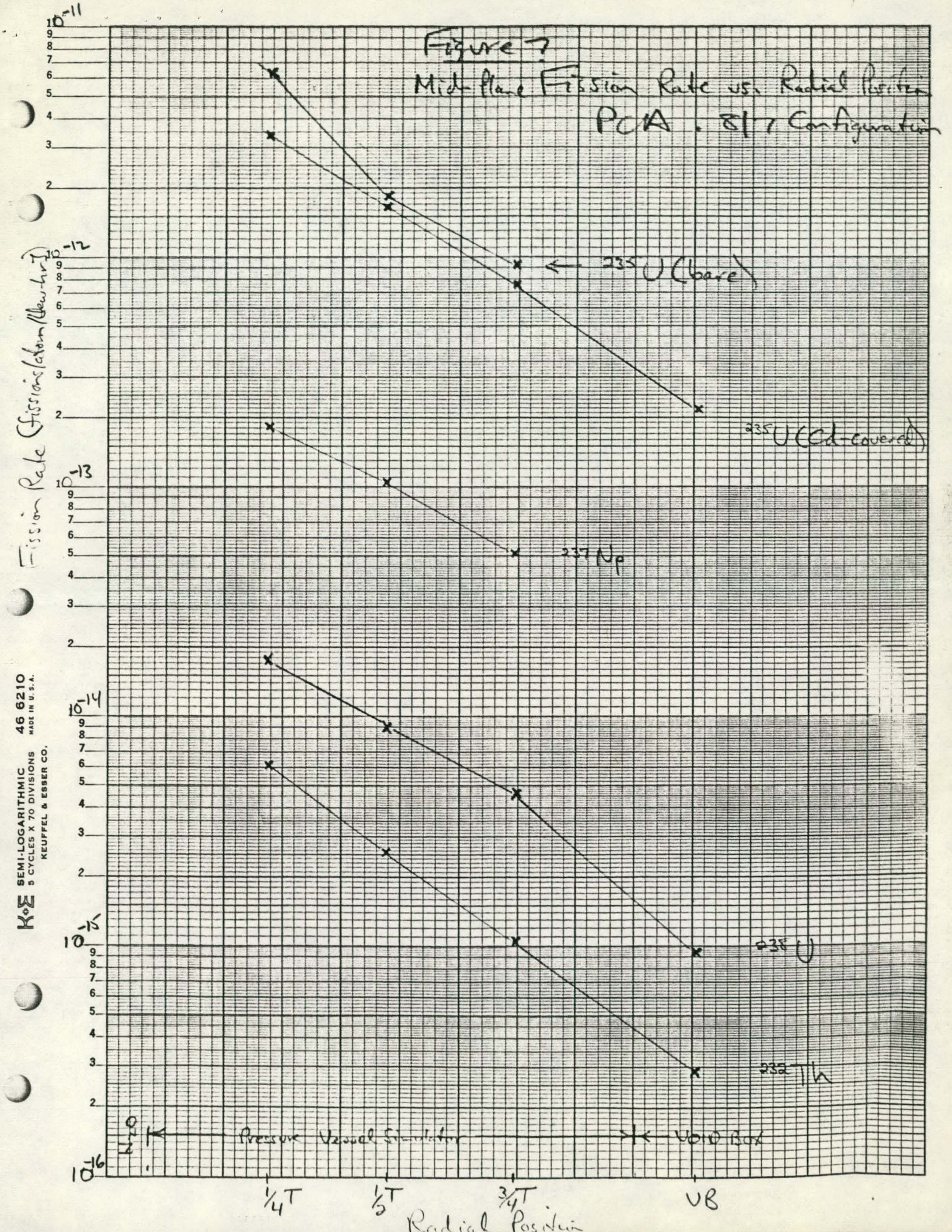


Figure 7
Mid-Plane Fission Rate vs. Radial Position
PCA . 8/7 Configuration
Fission Rate (fissions/atom/kw-hr)
235U (bare)
235U (Cd-covered)
237Np
238U
232Th
Pressure Vessel Simulator
Void Box
1/4T
1/2T
3/4T
VB
Radial Position
K+E SEMI-LOGARITHMIC
5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6210
MADE IN U.S.A.

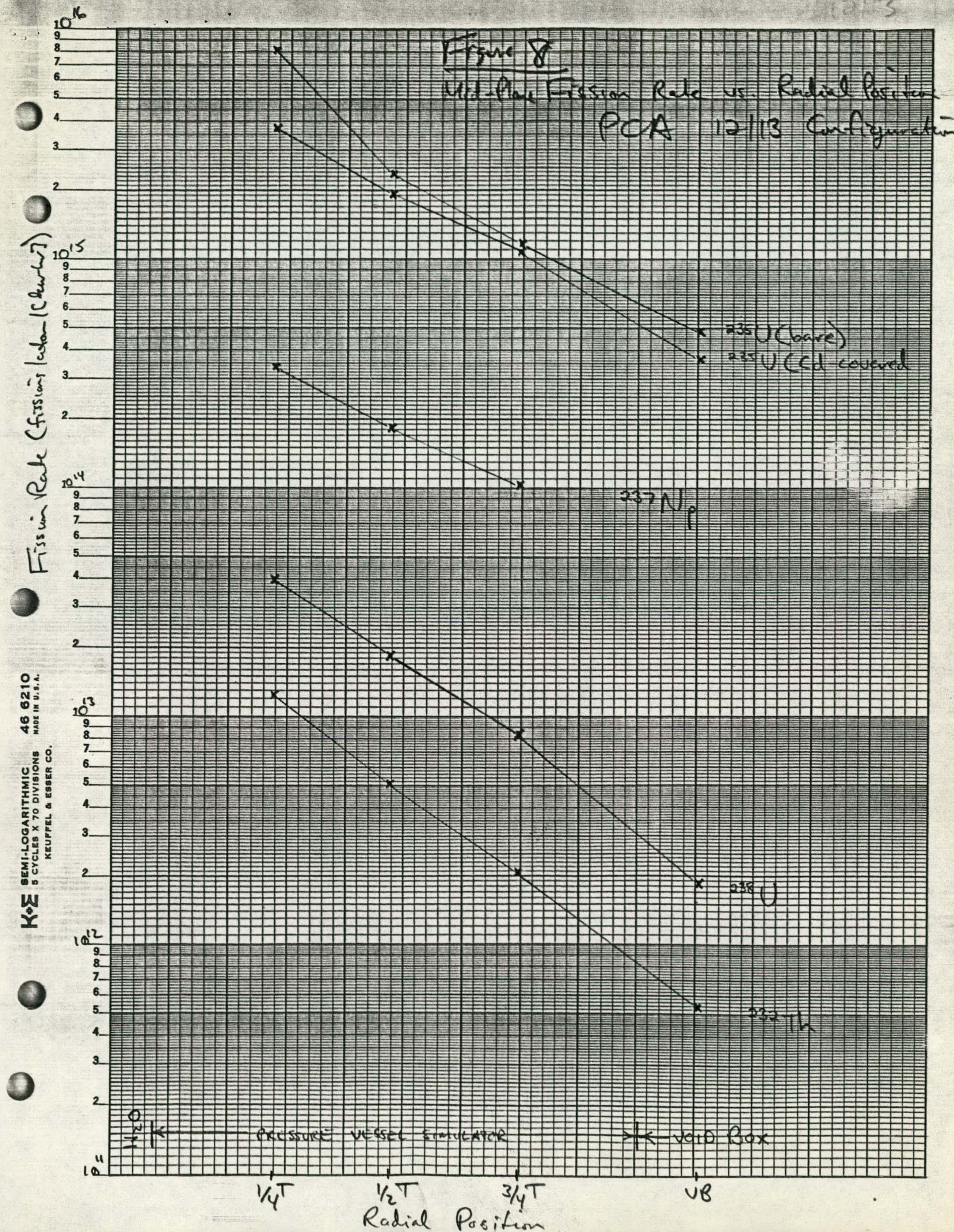


Figure 8
Mid-Plane Fission Rate vs. Radial Position
PCA 12/13 Configuration
Fission Rate (Fissions/atom [checked])
Radial Position
1/4T
1/2T
3/4T
VB
235U (bare)
235U (Cd covered
237Np
238U
232Th
H2O
PRESSURE VESSEL SIMULATOR
VOID BOX
K&E SEMI-LOGARITHMIC 46 6210
5 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.