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THE FISSION CROSS SECTION OF U²³⁸ FOR 14 MEV NEUTRONS

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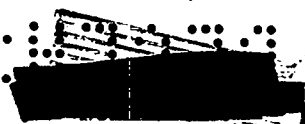
Warren Nyer

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Abstract

σ_{fission} of ^{28}Al for 14 Mev neutrons was measured with thin foils in a shallow ionization chamber using neutrons produced by the d-t reaction in the Cockcroft-Walton accelerator. A value of

$$\sigma_f = 1.13 \pm 0.03 \text{ barns was obtained.}$$

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The Fission Cross Section of U²³⁸ for 14 Mev Neutrons1. The Cross Section

Direct determination of a fission cross section involves measuring the fission rate of a known mass of material in a known flux. The fission cross section for neutrons of velocity v is

$$\sigma_f = \frac{f}{N \cdot nvt}$$

The quantities which must be measured are the following:

f = total fissions occurring in sample

N = atoms in sample

nvt = neutron flux at sample multiplied by the time

= "total flux"

2. Apparatus

The 14 Mev neutrons were produced with the Cockcroft-Walton accelerator using 200 kev deuterons on a tritium target¹.

¹ See forthcoming report on tritium filled metal targets by Elizabeth Graves, Maxwell Goldblatt, Donald Meyer, and Armando Rodriguez.

A parallel plate fission chamber was placed in the neutron beam. The ionization pulses in the chamber were amplified and then analyzed with a 10-channel discriminator. The apparatus is shown in figure 1.

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3. Measurements

The number of neutrons produced by the source is the integral of the "total flux" over the surface of a sphere.

Then
$$nvt = \frac{g(\theta)Q}{4\pi r^2}$$
 where $g(\theta)$ accounts for the variation of nv with the laboratory angle between the detector and the deuteron beam; and Q is the total number of neutrons produced by the source in t seconds.

Then
$$f = \frac{4\pi r^2 f}{N g(\theta) Q}$$

The flux at the foil could be different from the calculated value if the chamber walls were thick enough to scatter large numbers of neutrons. This effect was found to be negligible by performing a scattering experiment with a brass disc 1/8-inch thick.

a. Source Strength

Q is determined by counting the alpha particles of the reaction at some angle ϕ . The alpha counts α are related to the source strength by $\alpha = g_1(\phi)Q$, where $g_1(\phi)$ involves the solid angle of the detector and the angular distribution of the alphas. Both $g(\theta)$ and $g_1(\phi)$ were calculated for the beam energy used in this measurement by Donald D. Phillips², assuming the d-t

² To be published as an L.A. Report by D. D. Phillips

 reaction to be isotropic in the center of mass system.

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The agreement between σ_f measured at 45 degrees and at 90 degrees is an indication of the validity of this assumption. The cross section in terms of the measured quantities is:

$$r = \frac{4\pi r^2}{N.M(\theta)} \frac{f}{\alpha}$$

$M(\theta)$ is a calculated factor² relating the neutrons per unit solid angle at the angle θ per alpha particle per unit solid angle at the alpha counter angle of 114 degrees. The only significant error in $M(\theta)$ is in the area of the hole in the limiting diaphragm of the alpha-monitor. This is about one percent.

The pulse height distributions of the alpha-monitor pulses with an alpha shutter open and closed were measured with the 10-channel analyzer. The bias on the alpha-monitor scaler was then set so that the number of alpha pulses lost was equal to the counts gained from background. This was less than one percent of the total counts. The counts observed were equal to the alphas entering the chamber to within several tenths of a percent.

b. Location of the Source

It is possible for the center of the beam to be 1/8-inch away from the target center. This does not introduce any error in the monitor calibration, but it does require that r (see figure 1) be about 20 cm in order that the error in

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r^2 be less than three percent. The actual error was made considerably less than this by juggling beam controls to find the center of the target and keep the beam there.

c. Fission Rate

The gain on the amplifier was set so that the largest alpha-pulses from the 28 fell into the first channel of the analyzer. No pulses were observed in higher channels. The pulse height distribution with the beam on is shown in figures 2 and 4. The pulses in channel one are attributed to argon disintegrations and recoils and 28 alphas. The pulses in channels three and above are fissions. Channel two counts both fissions and argon reactions. That this introduces no significant error can be seen from the integral bias curves (figures 3 and 5). The total fissions are obtained by extrapolating the fission integral bias curve to zero bias. Since the portion of the integral bias curve due to fissions is almost flat and horizontal, this can be done precisely. The error is about 0.5 percent.

A measurement with a blank platinum foil was made. The pulses observed were mainly in channel one. The counts in channel two were negligible. No counts were observed in higher channels.

Only one other correction is necessary to obtain the number of fissions induced in the foil, namely the

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self-absorption correction. If all the fragments had the same energy and the foil were uniformly thick, this would be given by the following relation:

$$\text{total fissions} = \text{observed fissions} \left(1 - \frac{\text{thickness of foil}}{2 \text{ range of fragments in foil}} \right)^{-1}$$

Assuming the mean range of the 28 fragments in 28 is the same as the 25 fragments in normal uranium, this amounts to one percent for the $.2 \frac{\text{mg}}{\text{cm}^2}$ thickness of 28 used. This assumption can be in considerable error (400 percent) without introducing a large correction (3 percent). Neither this correction nor a back-scattering correction will be applied in this paper.

d. The Mass of the Foil

The masses of the foils supplied by R. Potter and J. Povelities of Group CMR-4 were determined by weighing and by alpha counting. The weights were 1.018 ± 0.001 mg. metal for foil A and 0.888 ± 0.006 mg. metal for foil B. The alpha-counting values agreed with these within the limit of accuracy of this method -- about two percent.

4. The Value of σ_f

The results of the measurements are summarized in the table.

Foil A $N = 2.58 \cdot 10^{18}$ $M(45^\circ) = 1.25 \cdot 10^7$
 Foil B $N = 2.25 \cdot 10^{18}$ $M(90^\circ) = 1.21 \cdot 10^7$

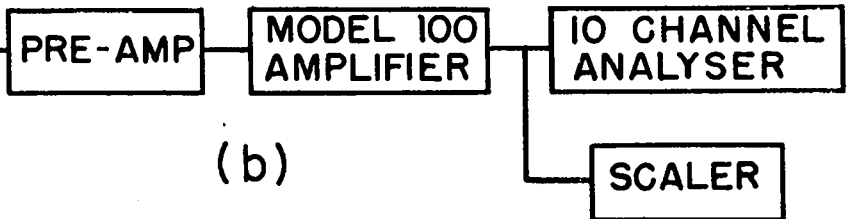
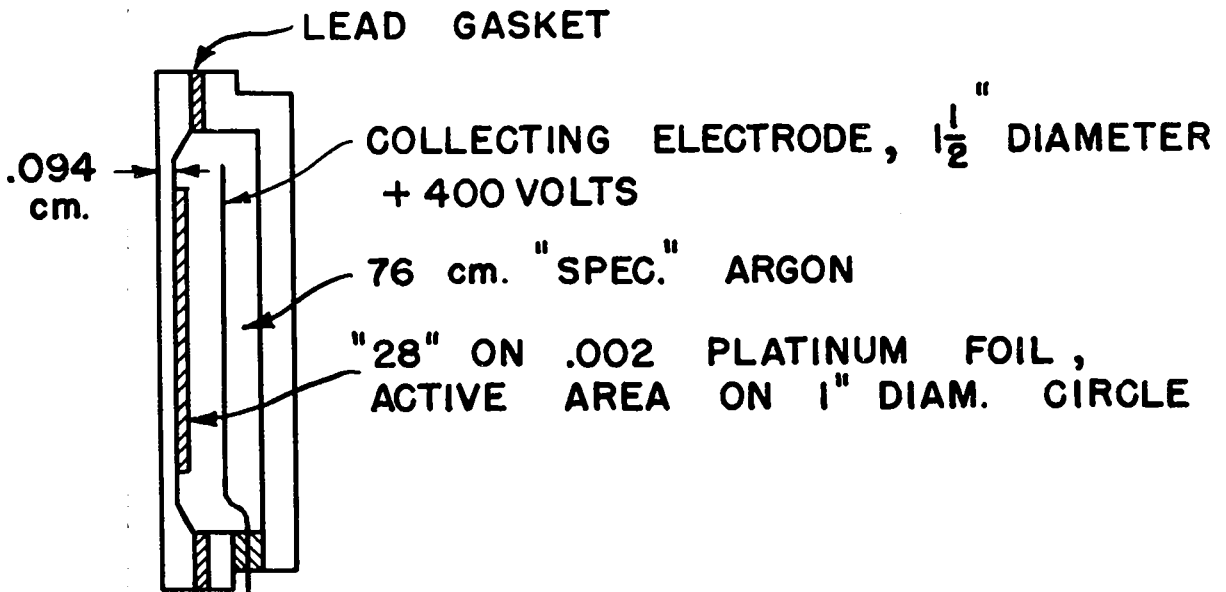
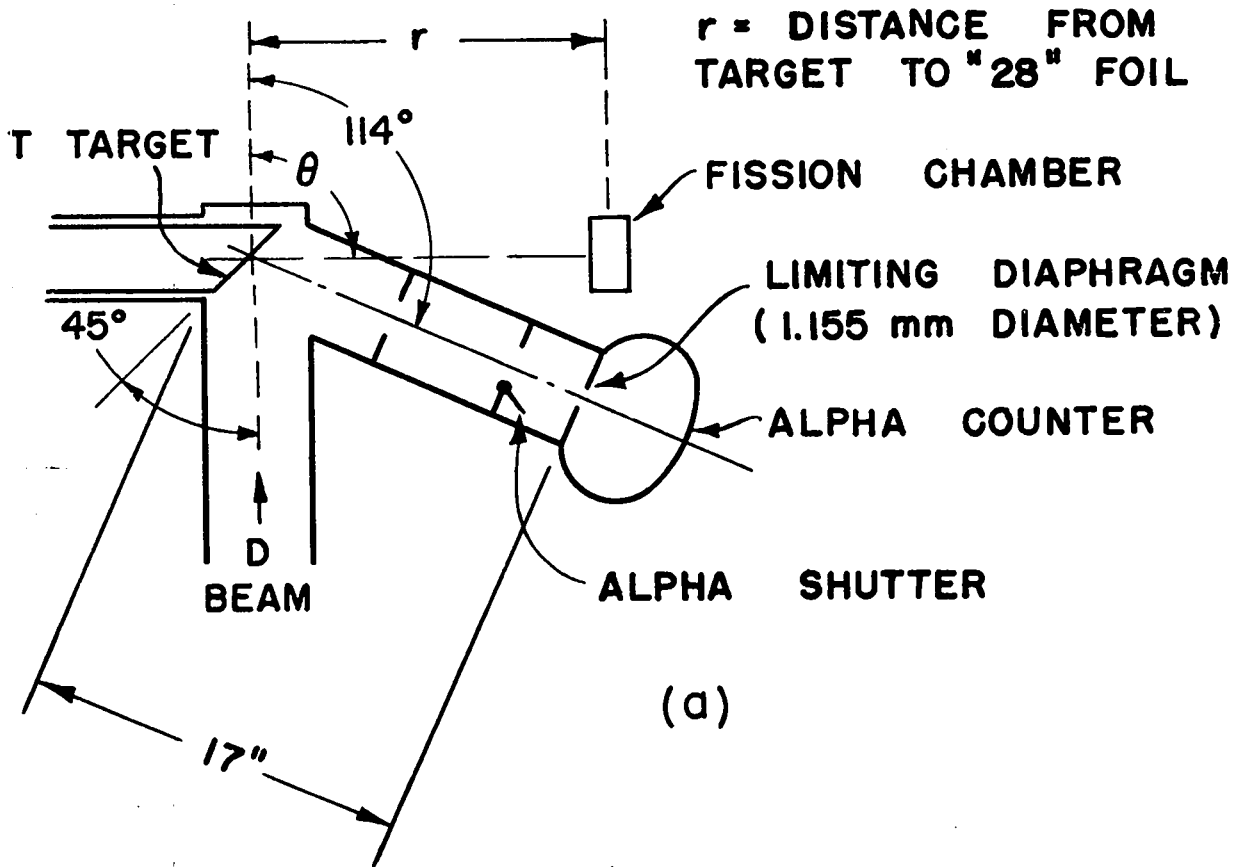
Foil	r cm from foil to target	θ angle between beam, foil	f fissions	α alpha counts/64	σ_f	
B	18.59	45°	1780	19 233	1.14	$\frac{\sum \text{cts} \cdot \sigma}{\sum \text{cts}} = 1.13$
B	10.09	45°	2358	7 486	1.15	
B	19.00	45°	2764	31 658	1.12	
B	22.18	90°	782	11 748	1.20	
B	22.18	90°	2282	36 741	1.13	
A	20.48	90°	1010	12 000	1.14	
A	20.47	90°	941	12 000	1.07	
A	20.21	90°	1292	15 940	1.07	
A	20.51	90°	620	7 587	1.11	
A	20.51	90°	979	11 834	1.13	

	r cm from target to foil	θ angle between foil, beam	f fissions (channel 2)	bgd. channel I	α alpha counts/64	
Platinum blank	10.00	90°	1	1809	1157	

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The weighted average of the cross-section values is $\sigma_f = 1.13$ barns. The statistical error in the number of counts is one percent. The deviations are larger than one would expect on this basis alone. However, the values for σ_f also include the errors in r , the foilweights, and the lack of uniformity in the 28 deposits on the platinum. The estimates given on the magnitudes of the errors and the internal consistency of the data indicate that the cross-section value $\sigma_f = 1.13$ barns is correct to within three percent.

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(b)

FIG 1

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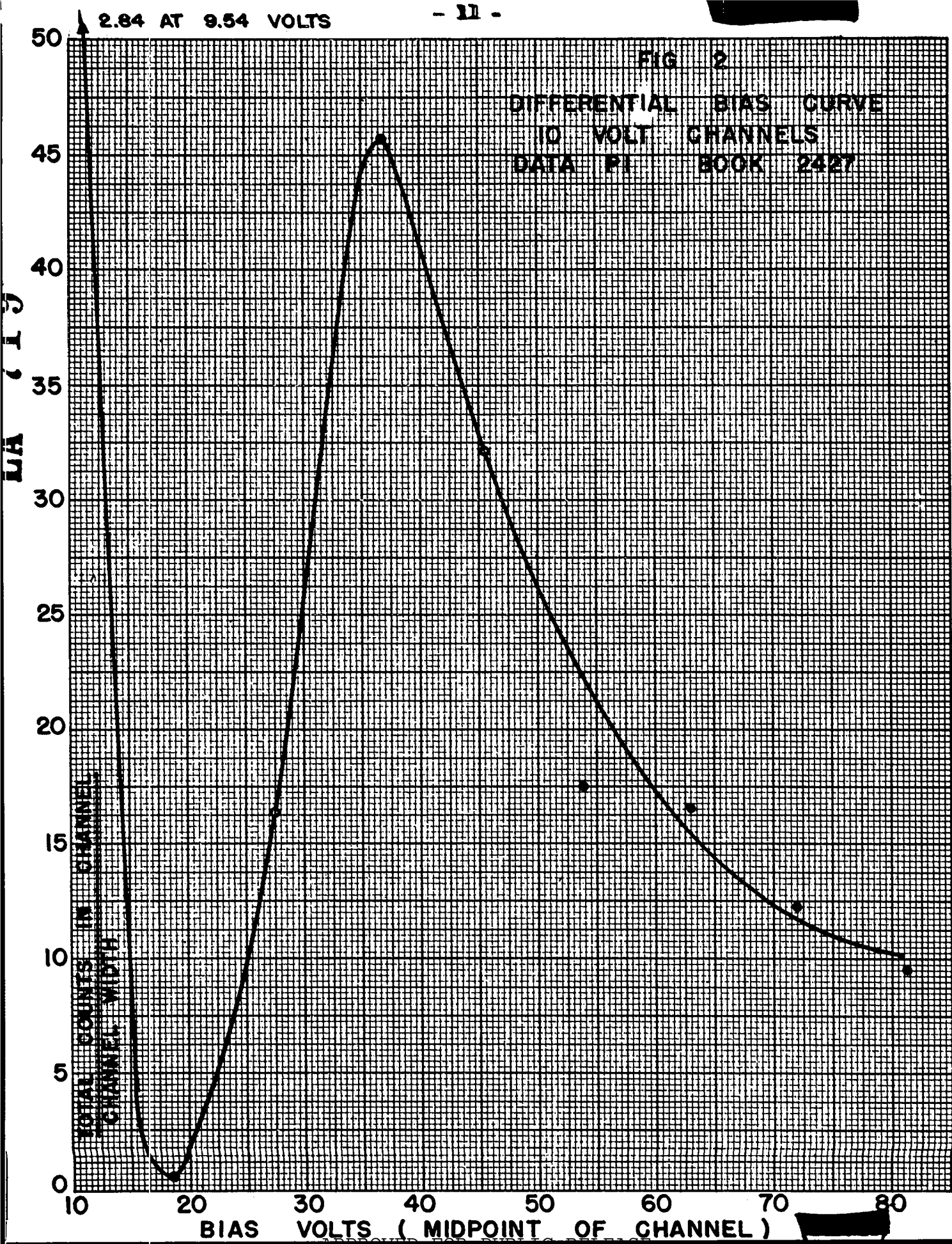


FIG 3
INTEGRAL BIAS CURVE
10 VOLT CHANNELS
DATA FI BOOK 2427

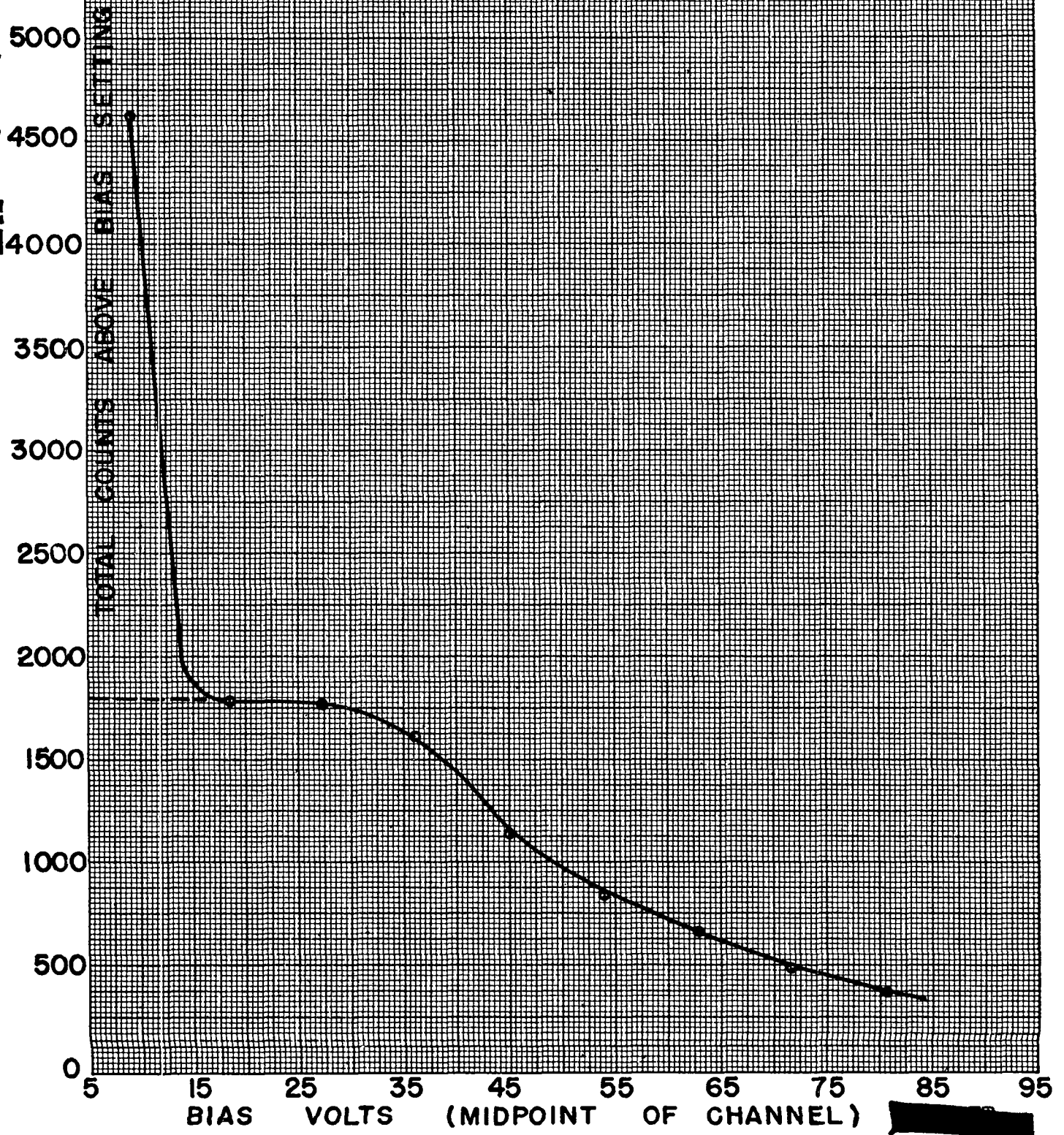
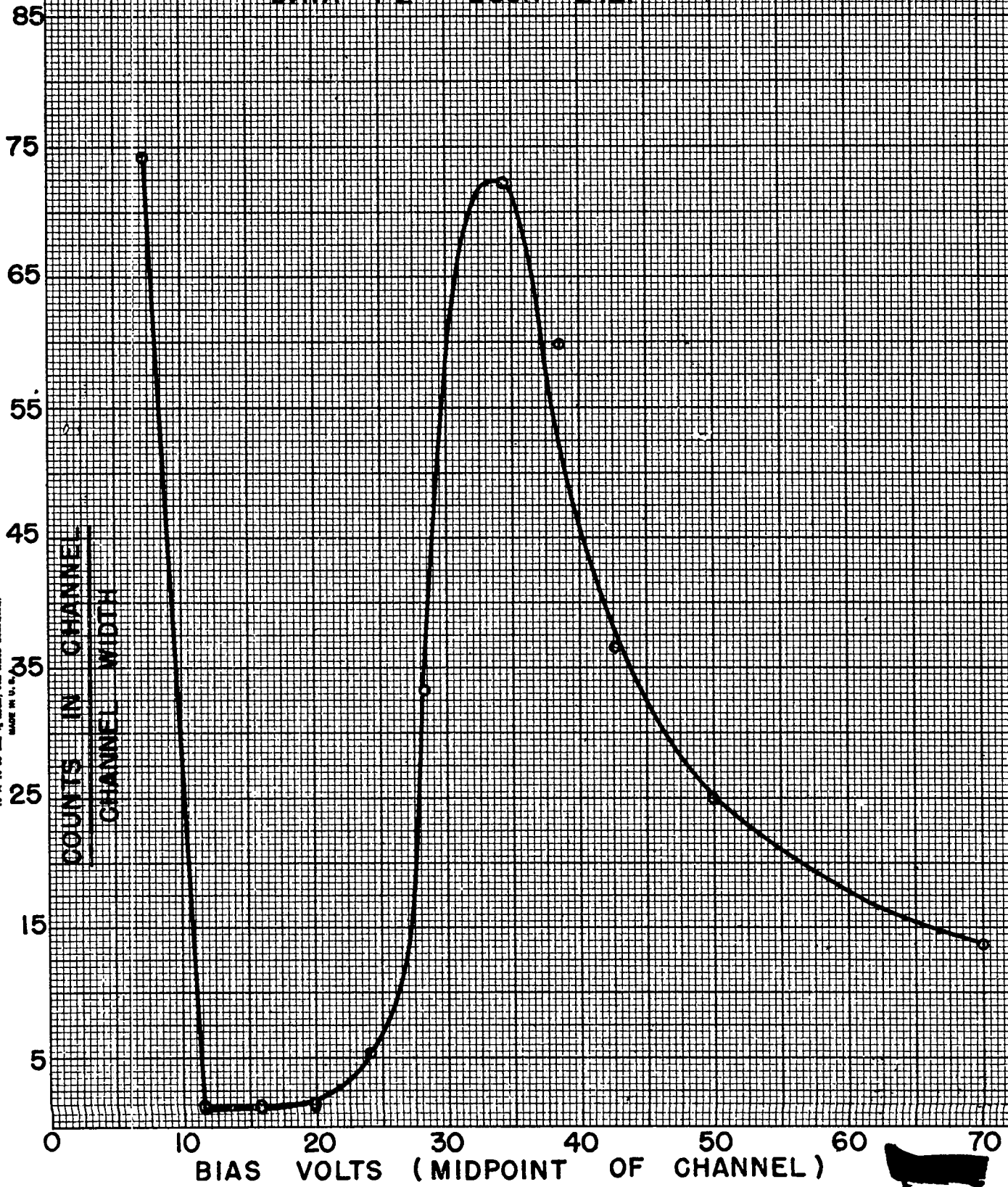


FIG 4

DIFFERENTIAL BIAS CURVE
5 VOLT CHANNELS
DATA P2 BOOK 2427

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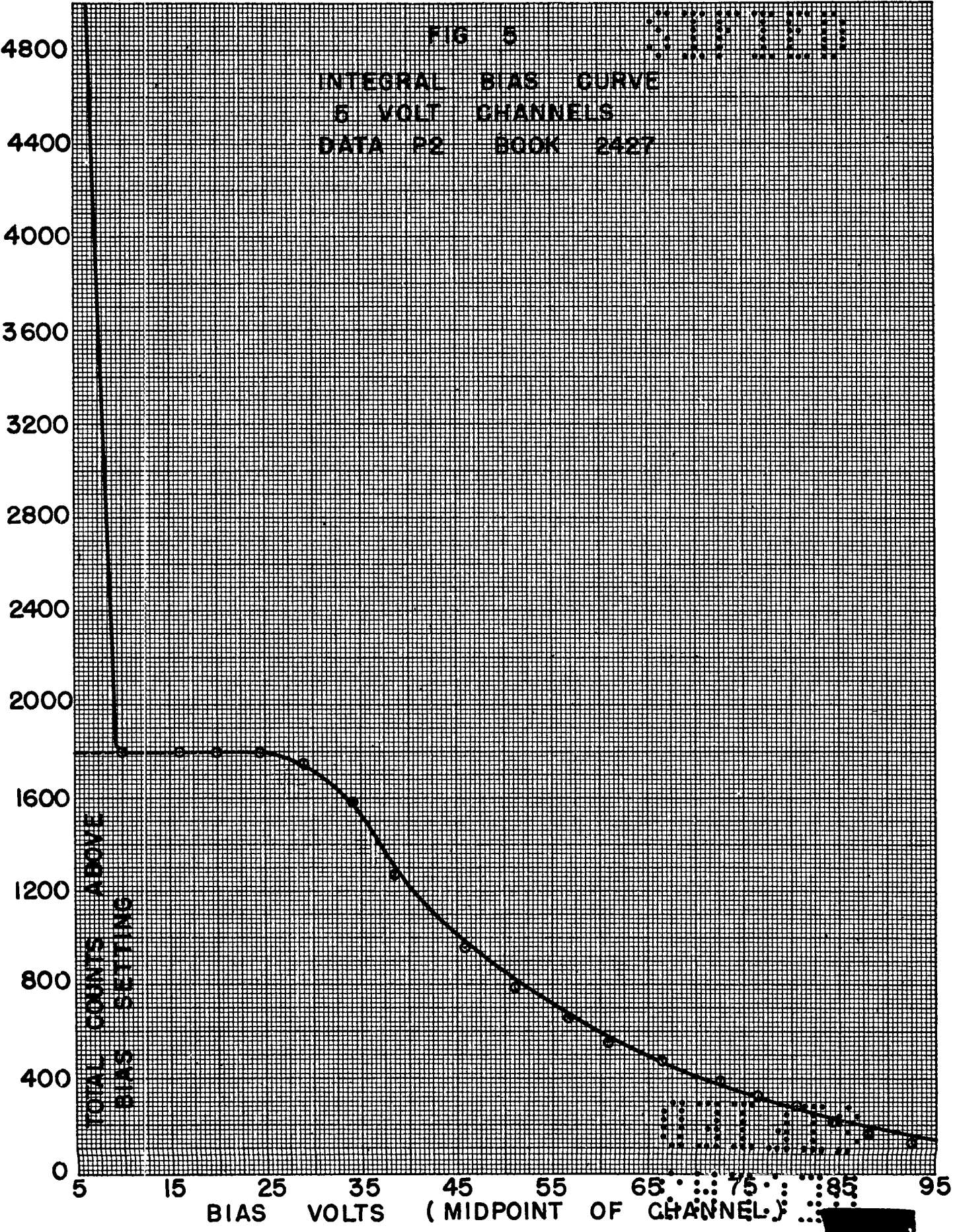
SCUFEL & ESSER CO., N. Y. NO. 88-15
10 X 10 to the 1/2 inch, 4th line abstract.
MADE IN U.S.A.



5500 AT 5 VOLTS

FIG 5

INTEGRAL BIAS CURVE
6 VOLT CHANNELS
DATA P2 BOOK 2427



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