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May 18, 1944

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LONG RANGE ALPHA PARTICLES EMITTED IN CONNECTION WITH FISSION

PRELIMINARY REPORT

May 18, 1944

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Physics - Fission

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ABSTRACT

Alphas are emitted in coincidence (i.e. within $5 \cdot 10^{-6}$ sec) with fission by 25 and 49. The maximum range observed corresponds to an energy of 16 Mev. About one alpha per 250 fissions is emitted by 25 and one alpha per 500 fissions by 49. The investigation is being continued.

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PRELIMINARY REPORT

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Alvarez reported (verbal communication) that a foil of 25 irradiated with slow neutrons emits charged particles (probably alphas) with a range of about 20 cm of air.

An experiment was made to determine the nature, energy and abundance of particles other than fission fragments and neutrons which are occasionally emitted in connection with the fission process. We have found that these particles are emitted in coincidence ($< 10^{-5}$ sec) with fission in 25 and 49, that they are alpha particles, and that their maximum energy is about 16 Mev. About one alpha per 250 fissions has been detected for 25, and one alpha per 500 fissions for 49.

A double chamber connected to twin linear amplifiers and counting circuits was used as a detector. The chamber was filled with argon and electrons were collected. A coincidence circuit registered events occuring simultaneously on each side of the chamber. The resolving time of the circuits was measured experimentally using the formula:

$$N_c = 2 N_A N_B t$$

N_c is rate of accidental coincidence counts.

N_A is counting rate of A side.

N_B is counting rate of B side.

t is resolving time in same units as above rates.

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With various single counting rates the resolving time was found to be from six to ten micro-seconds.

The chamber was so constructed that the sample foil acted as a high voltage electrode between two collecting electrodes which were connected to first amplifier tube grids. Thus the sample mounted on thin metallic foil could emit particles into either side or both sides. In our experiment the actual sample of uranium faced the chamber side which we will call A. The back of the foil faced into side B. The physical depth of side A was 0.6 cm and the physical depth of side B was 1.5 cm. A pressure of 4 atmospheres of argon was used, making an effective depth 5.7 cm air equivalent on side B and 2.3 cm air equivalent on side A.

The enriched sample used consisted of 0.220 mg of 25 electro-deposited on a thin platinum foil weighing 8 mg/cm^2. This foil was also backed with an additional layer of gold weighing 5 mg/cm^2 making an equivalent total of 12.2 mg/cm^2 of gold. With this arrangement and the bias used the natural uranium alpha particles and fission fragments were not detected in side B.

The chamber was irradiated with slow neutrons from the cyclotron. As a function of bias we obtained the following ratios between single counts on side B and counts on side A (B/A), and between coincidences and counts on side A (C/A). The fission rate on side A was maintained at about 4000 counts/min.

The non-coincident counts on side B may perhaps be due to a nitrogen impurity in the argon (tank argon was used); considerably less than 1% of nitrogen would account for the effect.

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BIAS IN MILLIVOLTS	B/A	COINCIDENCE/A
2.1	0.022	0.0010
4.0	0.0029	0.00066
5.2	0.0024	0.00045
6.3	0.0028	0.00035
7.0	0.0011	0.00029
9.0	0.0006	0.000163
12.0	0.00069	0.000103
14.7	0.0001	0.000025

These data are shown graphically in Fig. 4. When the curve is extrapolated to zero bias, it indicates approximately 1.5 coincidence counts per 1000 fissions.

The next part of the experiment was making of an absorption curve for the particles in coincidence with the fission counts. Various thicknesses of gold foils were used as absorbers. The bias of side B was maintained constant at 2.1 millivolts; and the fission rate in side A was maintained at about 3500 counts/min. The following ratios were obtained as a function of absorber thickness;

ABSORBER GOLD MG/CM^2	B/A	COINCIDENCE/A
12.2	0.032	0.0010
22.2	0.019	0.00077
37.2	0.0421	0.00043
53.2	0.039	0.00038

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ABSORBER GOLD MG/CM^2	B/A	COINCIDENCE/A
78.2	0.0365	0.00016
99.2	0.035	0.00009
124.2	0.055	0.000075
225	0.051	0.00010

These data are shown graphically in Fig. 5.

We are now able to determine the number of penetrating particles emitted per fission. The extrapolated bias curve gives a coincidence rate of 1.5 per 1000 fissions. To this we apply a correction factor of 1.3, representing an extrapolation of the absorption curve from 12.2 mg/cm^2 of gold (the absorber thickness at which the bias curve was run) to zero absorber thickness. In addition we allow for the fact that chamber side B subtends a solid angle 2π seen from the fissionable material, hence half the particles are lost to possible observation. We have finally:

Number per 1000 fissions = $1.5 \times 1.3 \times 2 = 4$ per 1000 fissions

Having bias and absorption curves for the particle, we are able to calculate its range and specific ionization, which in turn identify the particle and its energy.

The range is obtained from Fig. 5, which shows that the particle of maximum range is stopped by 90 to 100 mg/cm^2 of gold. Using 3.9 mg/cm^2 of gold as the equivalent in stopping power of 1 cm of air, we estimate the maximum range of the particle in air to be about 23 cm.

The range determination allows us to use the bias curve for the particle to show that its specific ionization is that of an alpha particle.

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Considerations leading to the conclusion that the particle is an alpha are as follows:

When collecting electrons in an ionization chamber of our type the pulse output of the chamber is determined by the product of the ionization charge and its displacement. Practically speaking the maximum pulse output from a particle of given energy is produced when the ionization track is from the sample mounted on a negative electrode and is parallel to that electrode. The total charge is then displaced the entire depth of the chamber. Referring to the polonium alpha bias curve, Fig. 3, we see that this particle, range 3.8 cm, energy 5.3 Mev, is able to produce a pulse output corresponding to 14.5 millivolts from our standard pulse generator.

As a further check we calculate the minimum output from the polonium alphas. The center of ionization charge is taken to be at 3/5 of the range of the particle. The chamber depth is 5.7 cm so the average charge is displaced 3.4 cm. The product of this factor and the energy of the particle should be proportional to the minimum pulse output, while the maximum output is proportional to 5.7 cm (depth of chamber) times the energy of the particle.

The minimum output should then be:

$$14.5 \times \frac{3.4 \times 5.3}{5.7 \times 5.3} = 8.7 \text{ millivolts.}$$

This is in agreement with the bias curve which breaks between 8 and 9 millivolts.

We have calculated the geometrical path in our chamber which would cause maximum pulse output from a particle whose range in air is 23 cm. This

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calculation takes into account that part of the range is spent in the absorber. Assuming the particle to be an alpha, it would spend about 11 Mev in the chamber. Its path would be such that the average charge displacement is 2.8 cm. Chamber pulse outputs then have the ratio:

$$\frac{\text{Max. Po alpha}}{\text{Max. F alpha}} = \frac{5.7 \times 5.3}{2.8 \times 11} = \frac{30.2}{30.8}$$

Thus the assumption that the particle under observation is an alpha leads to the conclusion that the maximum pulse heights of Po alphas and the unknown particle are the same.

From the bias curves of Po alphas and long range particles (Figs. 3 and 4) it is seen that both produced about the same maximum ionization pulse. It can therefore be concluded that the particle emitted in coincidence with fission of 25 (within a few micro-seconds) is an alpha of 23 cm of air range. From curves of Livingston and Bethe$^{1)}$ this corresponds to an energy of about 16 Mev.

The long range alpha particle observed with 25 fission was also observed in coincidence with 49 fission. A sample of about 2 mg of 49 (deposited as the fluoride on thin Pt) was used for the experiment. A collimating screen, necessary to reduce the alpha background on the fission side A, reduced the effective mass of the 49 to about 0.200 mg. The sample was irradiated with neutrons from two 1000·mc Ra + Be sources, with paraffin as the slowing medium. Fission counting rates of two to three hundred per minute were observed.

The absorption curve for the particles accompanying 49 fission is seen in Fig. 5. The maximum range of the particle appears to be the same as

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1) Livingston and Bethe, Rev. Mod. Phys., 9, 266 (1937).

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that of the alpha from 25 fission, within the limits of the experimental error.

The bias curve for the 49 particle is shown in Fig. 4. The difference in shape of the 25 and 49 curves may be accounted for by the additional absorber used for 49, which has the effect of eliminating the particles which made very small pulses on the 25 run. The maximum ionization pulse height is very close to that of the 25 alpha; this fact, together with the range identity, establishes the 49 particle as an alpha of maximum energy of about 16 Mev.

The number of alpha particles emitted in coincidence with 49 fission is computed from the data exactly as before. The result obtained is 2 alphas per 1000 fissions.

This investigation is being followed up with the purpose of finding for both 25 and 49:

(1) The energy distribution of the alphas.

(2) The possible presence of protons.

(3) The time relation of the emission of the charged particles to the fission.

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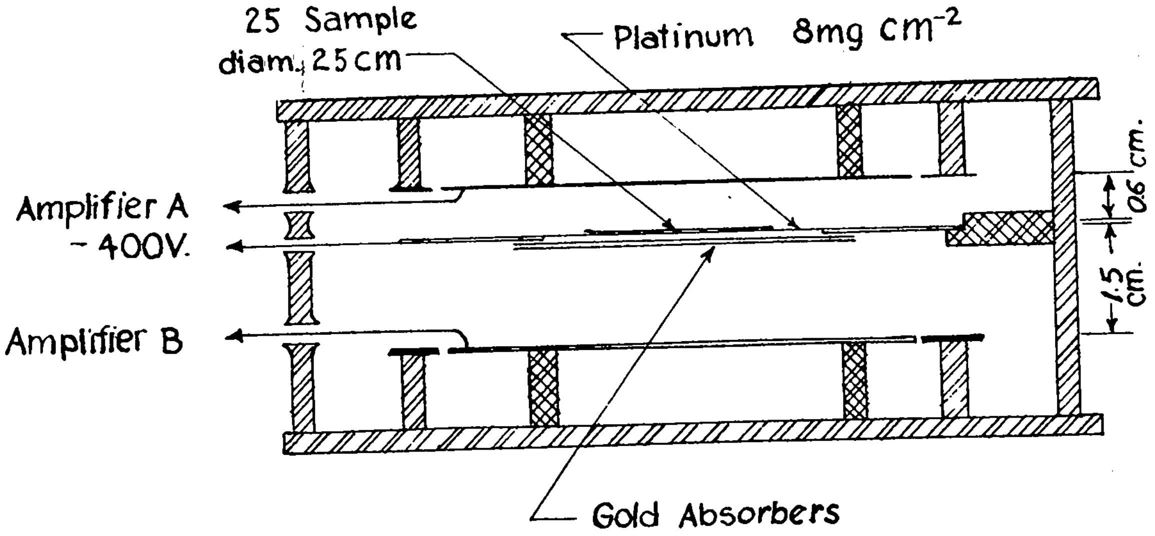

FIGURE 1

IONIZATION CHAMBER

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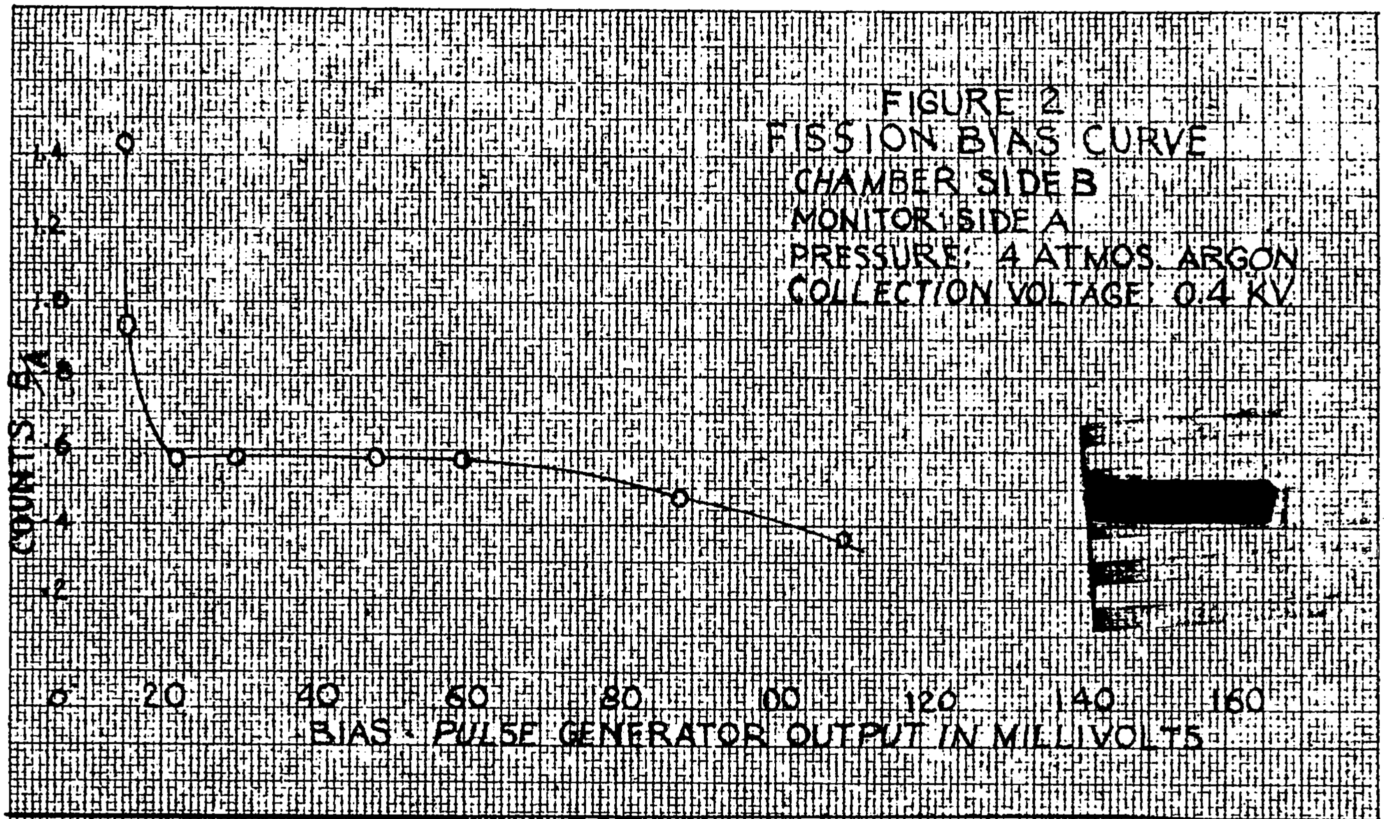

FIGURE 2
FISSION BIAS CURVE
CHAMBER SIDE B
MONITOR SIDE A
PRESSURE: 4 ATMOS ARGON
COLLECTION VOLTAGE: 0.4 KV

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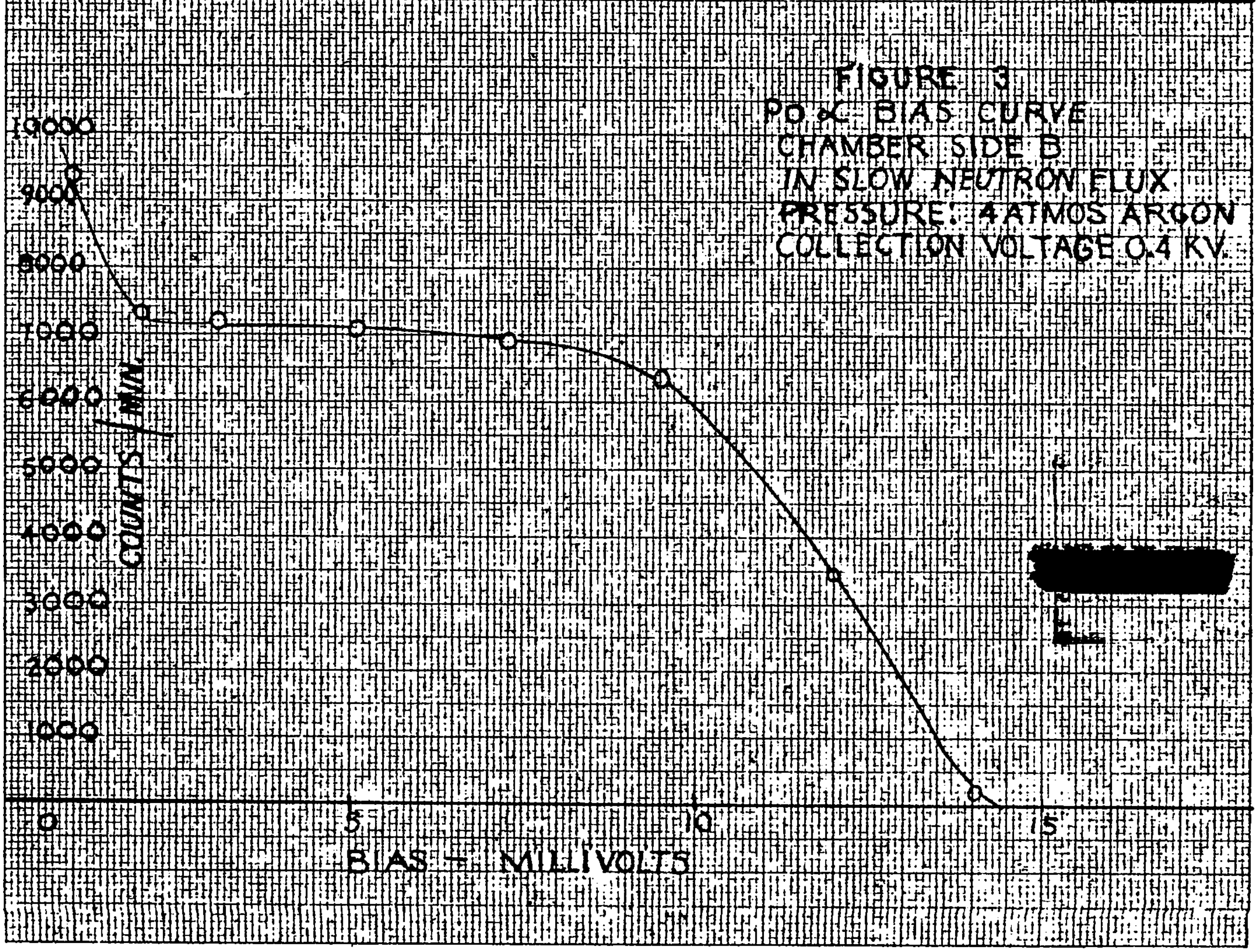

FIGURE 3
Po α BIAS CURVE
CHAMBER SIDE B
IN SLOW NEUTRON FLUX
PRESSURE: 4 ATMOS ARGON
COLLECTION VOLTAGE 0.4 KV.

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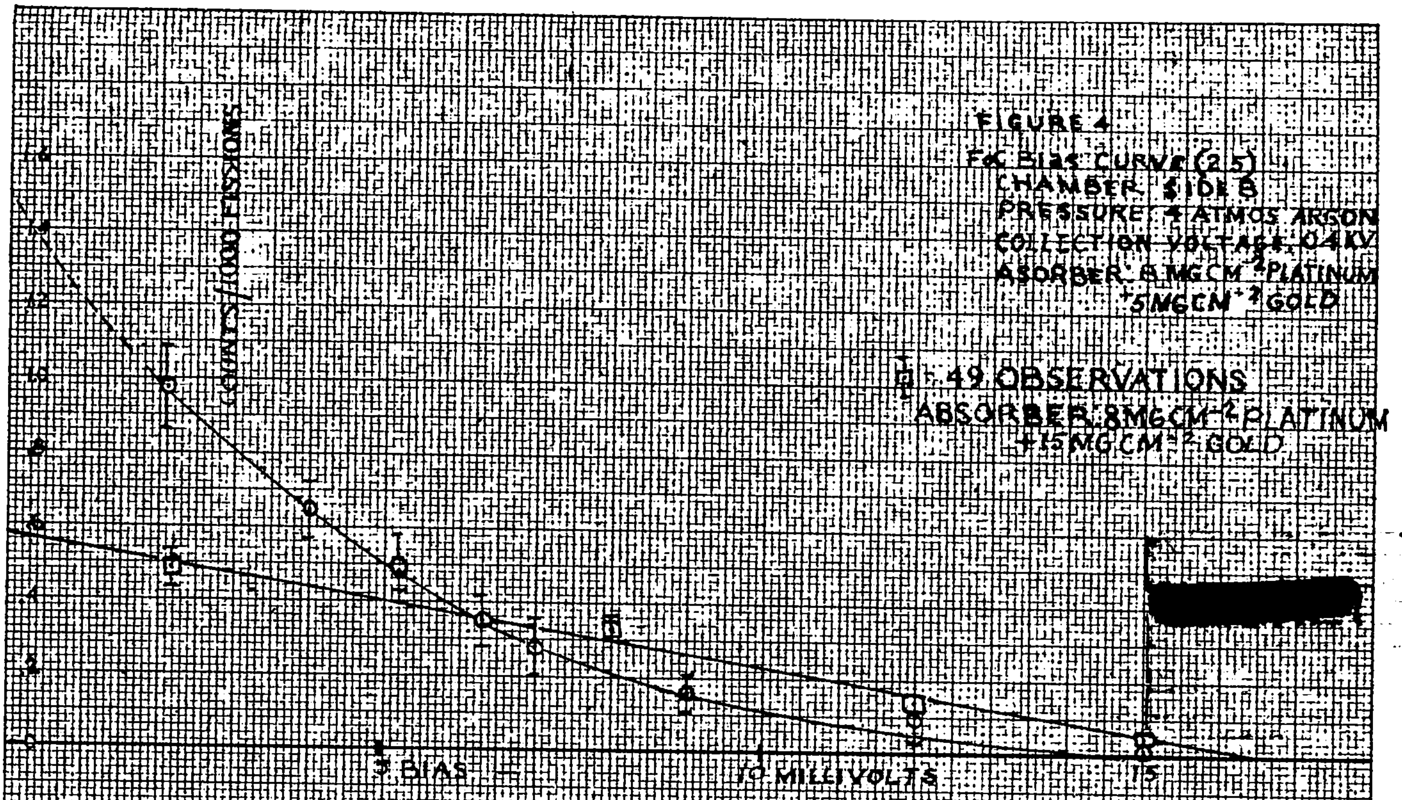

FIGURE 4
F-C BIAS CURVE (25)
CHAMBER SIDE B
PRESSURE: 4 ATMOS ARGON
COLLECTION VOLTAGE: 0.4KV
ASORBER: 8 MGCM⁻² PLATINUM
+5MGCM⁻² GOLD

□ : 49 OBSERVATIONS
ABSORBER: 8MGCM⁻² PLATINUM
+15MGCM⁻² GOLD

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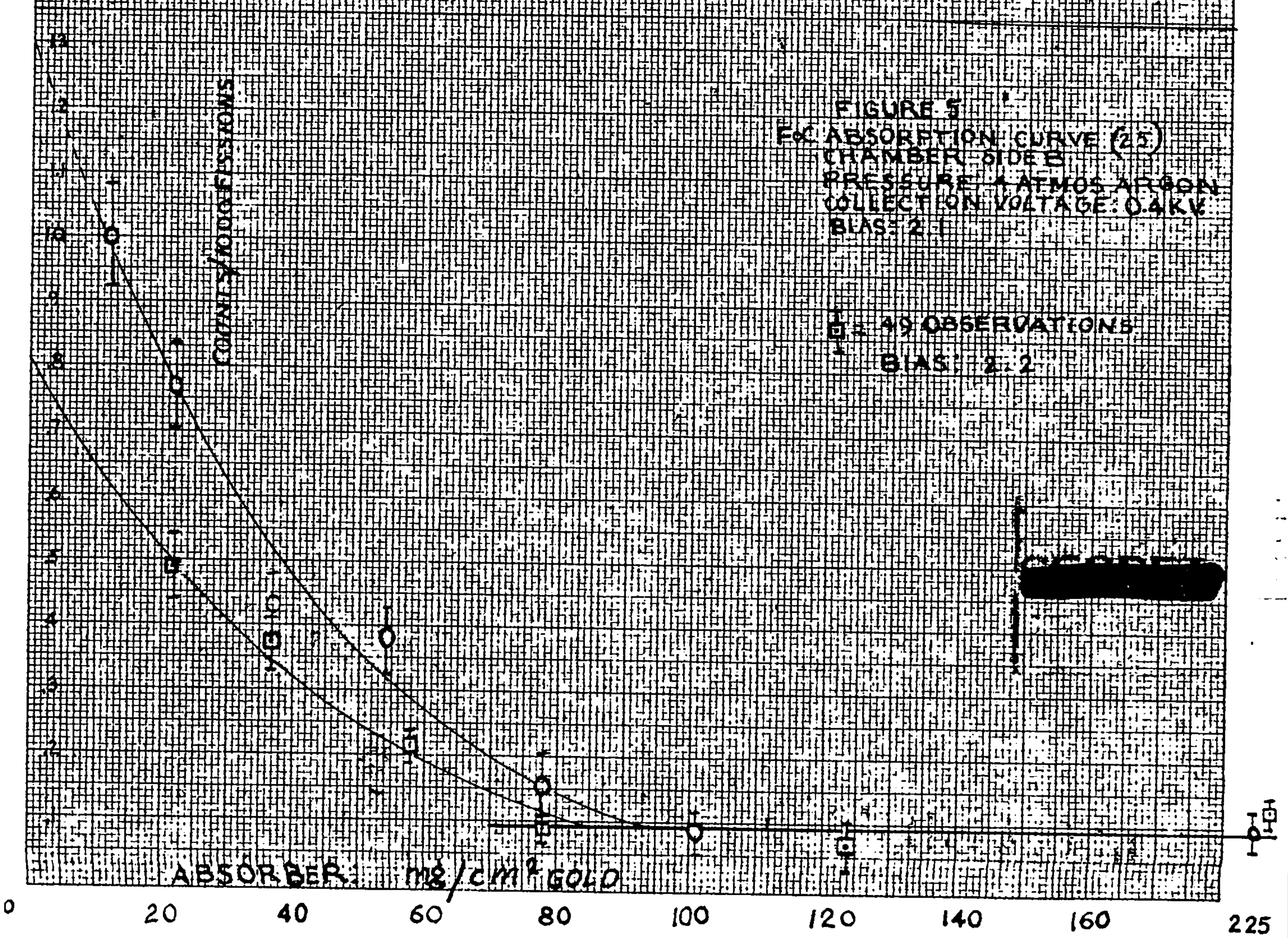

FIGURE 5
F-C ABSORPTION CURVE (25)
CHAMBER SIDE B
PRESSURE: 4 ATMOS ARGON
COLLECTION VOLTAGE: 0.4KV
BIAS: 2.1

□ : 49 OBSERVATIONS
BIAS: 2.2

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