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BORON TRIFLUORIDE NEUTRON DETECTOR FOR LOW NEUTRON INTENSITIES

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ABSTRACT

A sensitive boron trifluoride ionization chamber for the detection of weak neutron sources is described. Its efficiency for Ra-Be neutrons is about 2 percent with a background of 15 c/min.

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BORON TRIFLUORIDE NEUTRON DETECTOR FOR LOW NEUTRON INTENSITIES

In several problems interesting for this project it is important to detect the total number of neutrons emitted by a relatively small source. For example, the number of neutrons emitted by a polonium source mounted on platinum or the number of neutrons emitted by samples of 49 due to (α,n) reactions on impurities or the neutrons emitted by spontaneous fission. A few months ago the problem of building a sensitive detector was considered by Dodson and Segre[1] and two methods looked most promising; the use of the Szilard-Chalmers extraction of a suitable substance activated by the n-γ reaction or a boron trifluoride counter.

In this paper we shall report the results attained up to date with the boron trifluoride chamber.

The (n, α) reaction of B^{10} has been known for many years[2] and has been extensively used to detect slow neutrons by filling proportional counters, and ionization chambers with gaseous boron compounds, most commonly BF_3, and detecting the alpha-particles emitted under neutron bombardment. E.g., using several proportional counters in parallel, Roberts[3] has studied the neutron yields of polonium alphas bombarding light elements.

In the Roberts experiments, the efficiency of the detector for Po-Be neutrons was 4×10^{-3} with a background of 20 counts/minute. We define efficiency of the detector as the ratio of the number of pulses in the final register

1) LAMS-63
2) Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, Segre, Roy. Soc. Proc., A-149, 522 (1935)
3) CF-864

to the total number of neutrons emitted by the source.

For a weak neutron detector it is very important that this efficiency be high and at the same time the background of the apparatus be low. In the instrument described hereafter, we have an efficiency of about 2×10^{-2} with a background of 15 pulses per minute for Ra-Be neutrons.

The ionization chambers used are of two models, (Fig. 1 and 2) which differ only in their dimensions. The diagrams are self-explanatory to a great extent. The inner collecting electrode is supported by a Covar-glass seal. The apparatus is made of steel and ordinary rubber is used for the gaskets. The chambers were filled with specially pure BF_3 prepared by decomposition of benzene-diazonium fluoborate ($C_6H_5N_2BF_4$). This gas was prepared by Mr. H. Russell, Jr. in Group C-4 and behaved very differently from BF_3 taken from an Ohio chemical commercial tank or from the commercial gas roughly purified by fractional distillation.

The instrument was connected to a linear amplifier with a time of rise of 0.2 μsec and to a conventional counting circuit. We often had serious disturbances due to sparking on the glass surface insulating the high tension electrode from ground. This defect was satisfactorily remedied by coating the two surfaces of the glass with ceresin wax and also fastening to the glass, with ceresin, 2 pyrex glass rings inside and outside the ionization chamber so that the electric field is perpendicular to the surface of the insulator.

The chamber was sunk in the center of a paraffin cube of 50 cm side and paraffin was piled upon the opening of the chamber, Fig. 8.

In order to have an idea of the efficiency to be expected, a Ra-Be source was put in the center of a cylindrical cavity in a water tank of the same dimensions as the paraffin block and the neutron density in the cavity was meas-

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ured by activating indium foils. The source emitted 2 x 10^6 n/sec. For a cylinder 17 cm in diameter and 18 cm high with the upper opening on level with the water surface we obtain an nv = 1300 n/cm^2 sec. With the same cylinder sunk 10 cm deeper we have nv = 2320. A smaller cylinder (8 cm diameter and 25 cm high) with the upper opening on the level of the water gives nv = 2380.

From these numbers, assuming the cavity filled with BF_3 and neglecting the reduction in nv produced by the gas, one would expect an efficiency of 5.6, 9.9, and 2.0 percent respectively. These numbers should be reduced for the depression in nv produced by the gas. This correction may be a factor 2 or more and is larger for the larger chambers.

The typical behavior of the small chamber at constant bias and source as a function of the collection potential is given in Fig. 3 in which curve (a) is for ordinary BF_3 and curves (b) and (c) for the specially prepared gas. Curve (b) was taken at a pressure of 68 cm of Hg and the pressure for curve (c) was 135 cm of Hg. It is seen that saturation is reached only in curves (b) and (c). In Fig. 4 we give the counting rate as a function of bias at constant collecting voltage.

More extensive tests have been made on the large chamber for which we give the counting rate versus voltage curve at constant bias and constant source in Fig. 5 and the counting rate versus bias curve at a constant collection voltage of 4500 volts in Fig. 6. At this voltage the background is about 15 c/min.

The efficiency of the chamber is expected to be a function of the energy of the neutrons, being higher for lower energy neutrons. This is mainly because low energy neutrons diffuse away from the chamber with more difficulty and hence have a better chance of being captured by the boron trifluoride.

In order to have a more quantitative estimate of the importance of these

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effects we have measured the efficiency for Ra-Be neutrons, Po-Be neutrons, and for Y-Be photoneutrons (energy about 200 keV) under various geometrical conditions. In Table I we report the efficiencies measured (see Fig. 8), a) with the source on the axis of the chamber at 2 cm from the bottom of the inner electrode; b) in the same position but with a paraffin plug 15 cm in height placed directly above the source; c) in the paraffin block on a radius perpendicular to the axis of the chamber at 2 cm above the bottom of the inner electrode and at a distance from the axis given in column 1 of the table. The plug was in the chamber during these measurements. This table is represented graphically in Fig. 7.

TABLE I

Percent efficiency

Distance from chamber axis (centimeters)	Ra - Be	Po - Be	Y - Be
0 (a)	1.39	1.02	3.72
0 (b)	1.86	1.29	4.52
5.7	1.77	1.33	4.16
7.7	1.67	1.30	3.18
9.7	1.38	1.07	2.00
11.7	1.00	0.82	1.13
13.7	0.68	0.61	0.59
15.7	0.42	0.43	0.30
17.7	0.32	0.30	0.13
19.7	0.21	0.23	
21.7	0.14	0.14	
23.7		0.10	

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It will be noticed that the efficiency at small distances from the axis of the chamber is higher for the low energy neutrons and at large distances it is higher for the high energy neutrons. At 12.7 cm the efficiency is the same for both Y-Be and Ra-Be neutrons. An investigation of the intensity observed as a function of the distance is obviously very desirable when using this detector with an unknown source. In order to use the chamber for absolute measurements a calibration is obviously necessary and the most appropriate sources are probably; Ra-Be, Y-Be, Po-Be, Po-B, spontaneous fission neutrons. For the latter we obtain 0.9 counts per gm-hr which on the basis of 54 n/gr hr emitted spontaneously gives an efficiency of 1.67 percent.

The chamber works without inconvenience even when the source emits gamma rays up to about 2 mC Ra equivalent.

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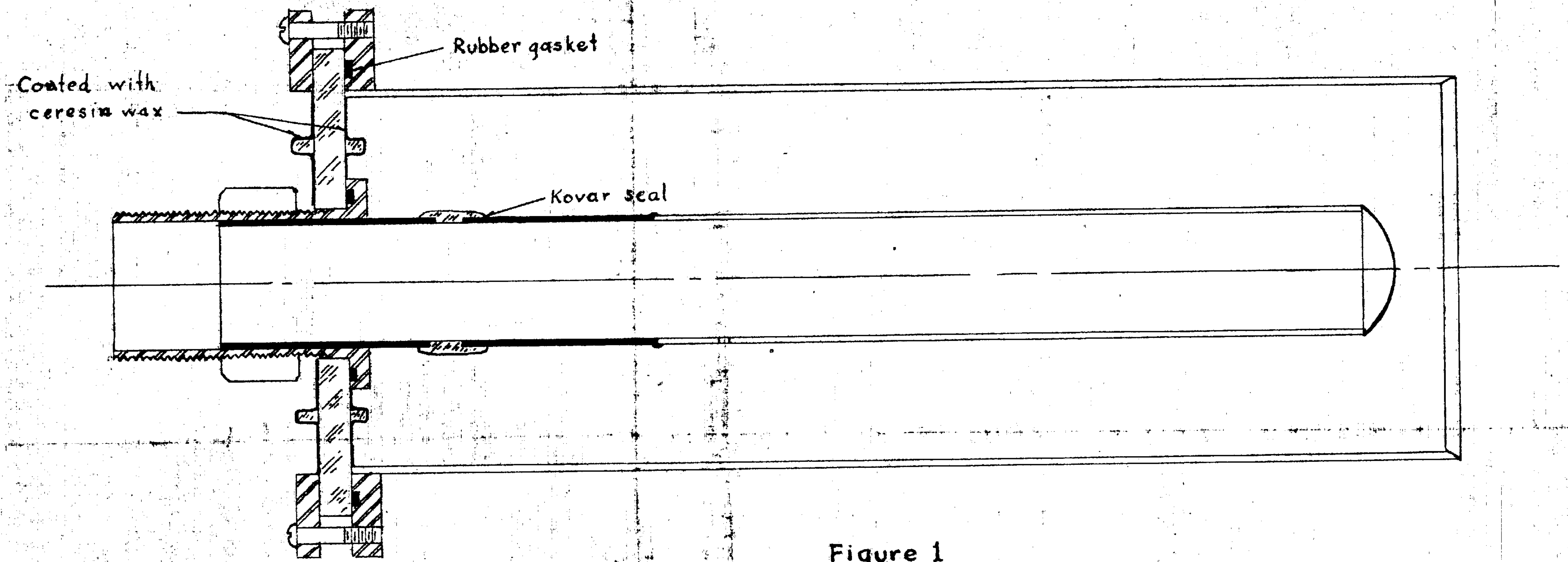

Figure 1

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Scale 1:1

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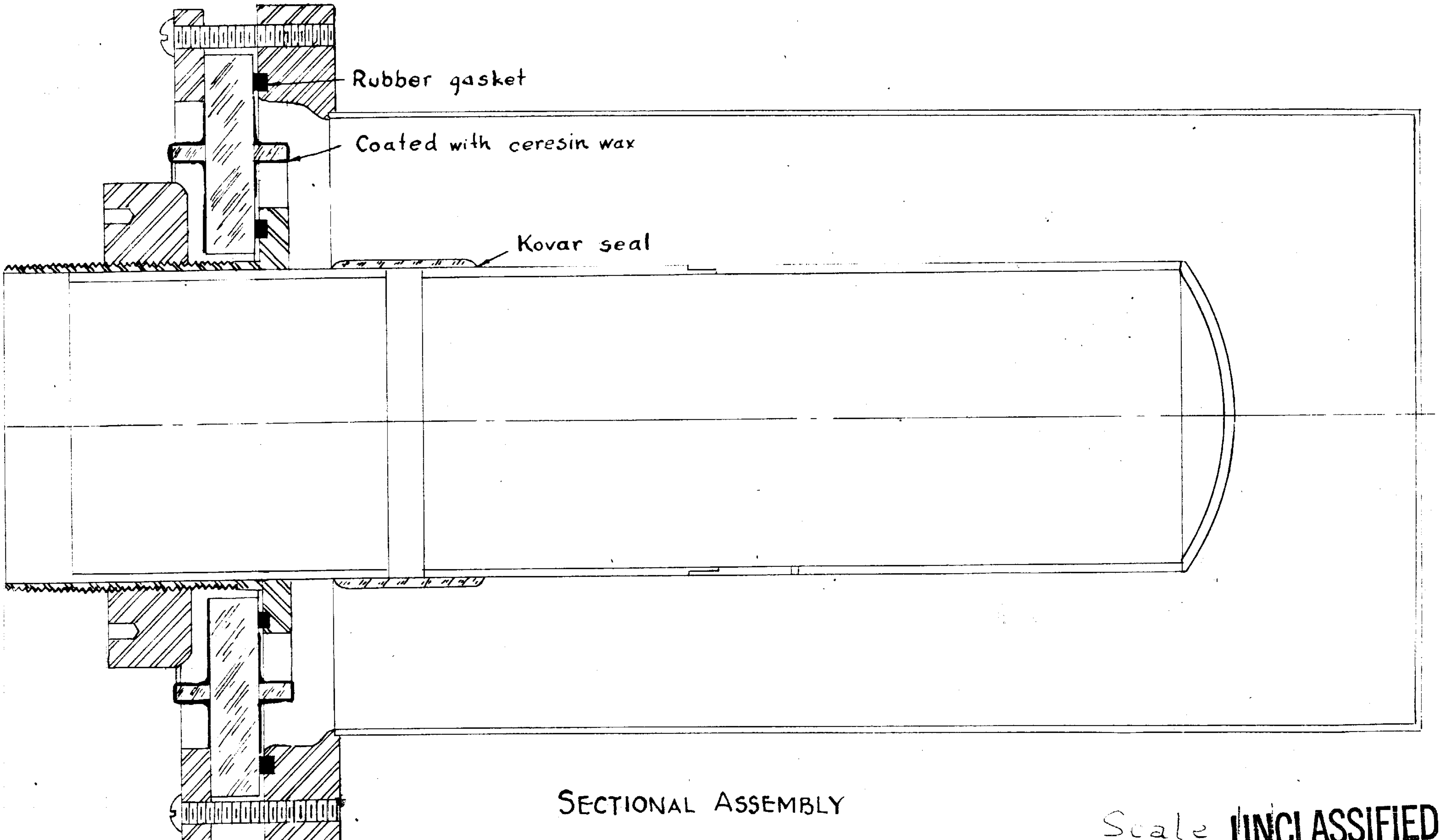

SECTIONAL ASSEMBLY

FIG. 2

Scale

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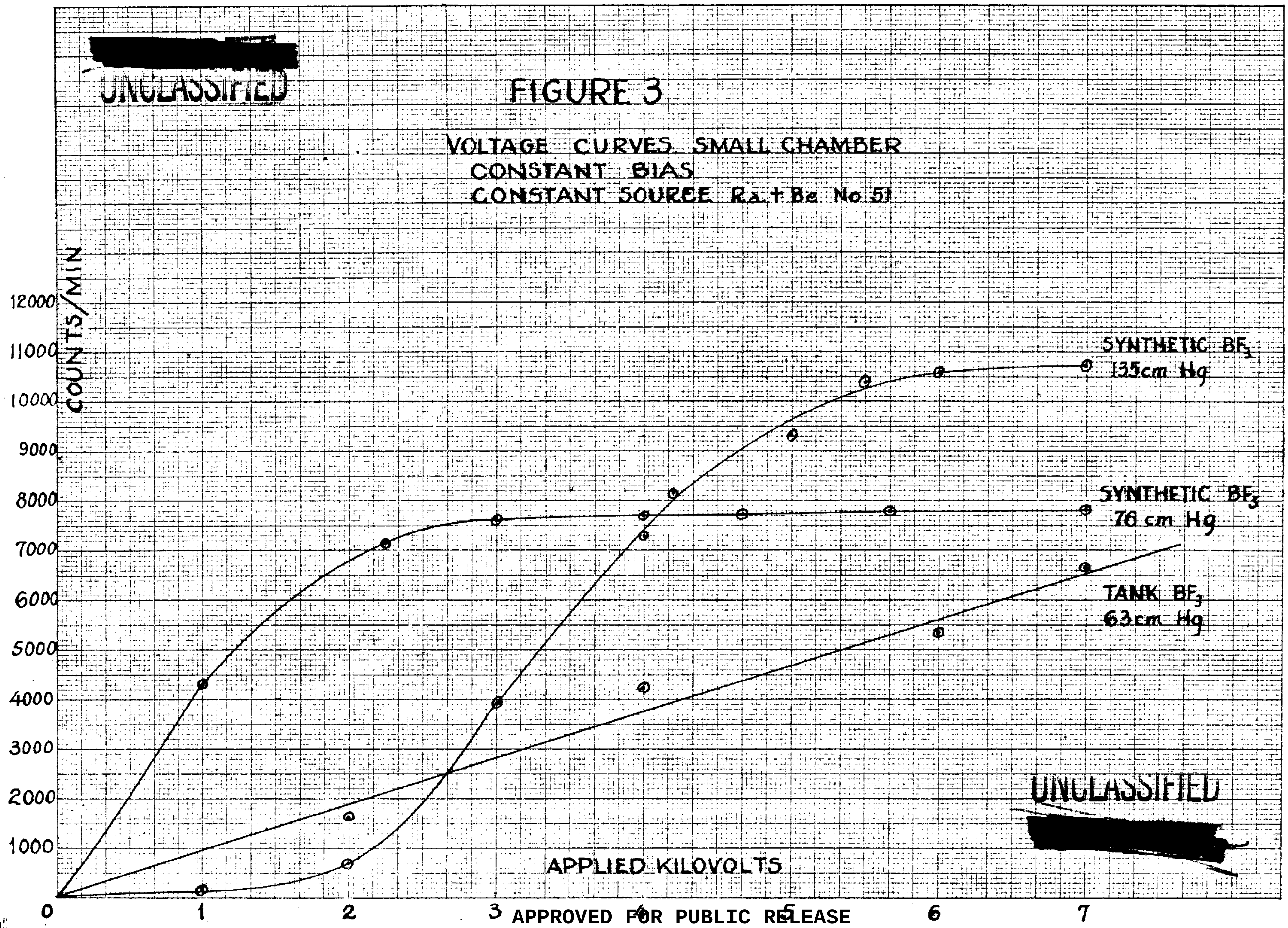
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FIGURE 3
VOLTAGE CURVES SMALL CHAMBER
CONSTANT BIAS
CONSTANT SOURCE Ra + Be No 51
COUNTS/MIN
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
7
SYNTHETIC BF3
135cm Hg
SYNTHETIC BF3
76 cm Hg
TANK BF3
63cm Hg
APPLIED KILOVOLTS
UNCLASSIFIED
[redacted]

[redacted]

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FIGURE 4

BIAS CURVE
SMALL CHAMBER
SYNTHETIC BF_3: 134.7 cm Hg
CONSTANT COLLECTION VOLTAGE: 6 K.V.
CONSTANT SOURCE: Po + Be

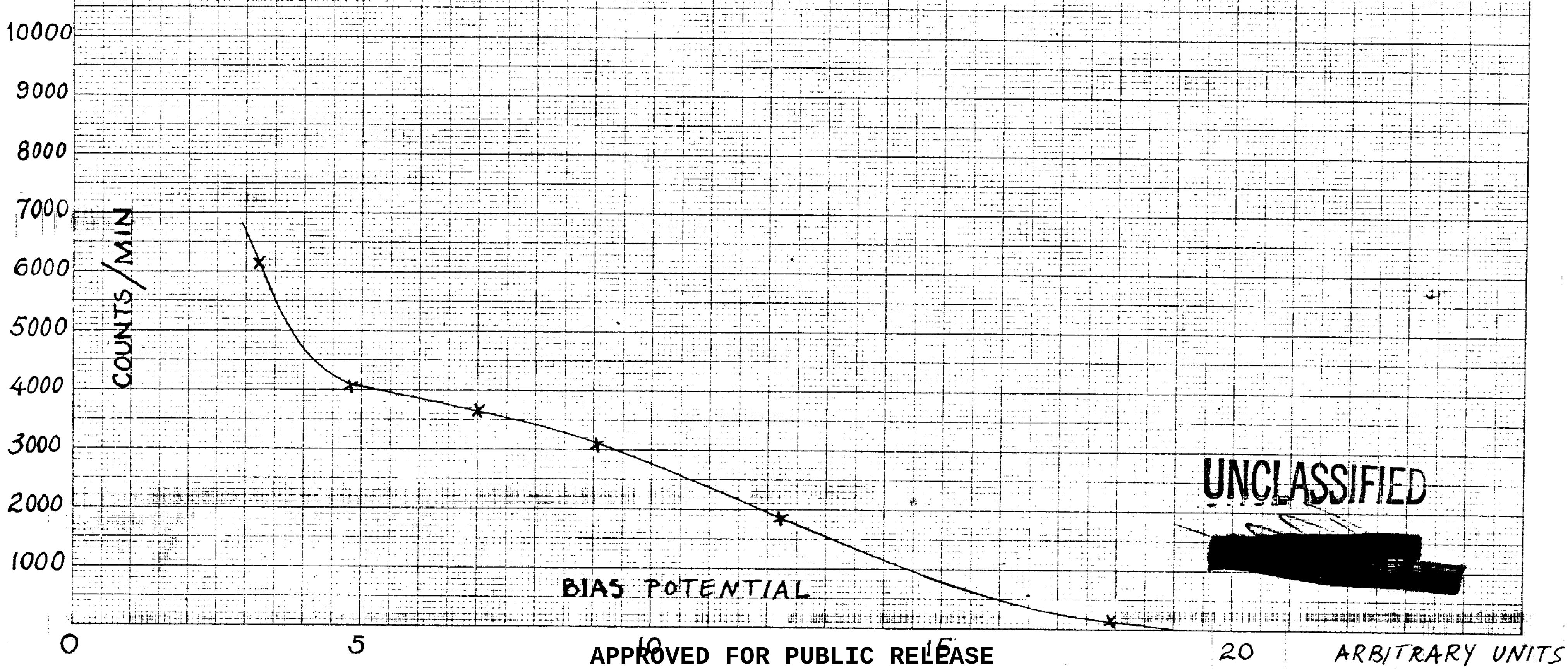

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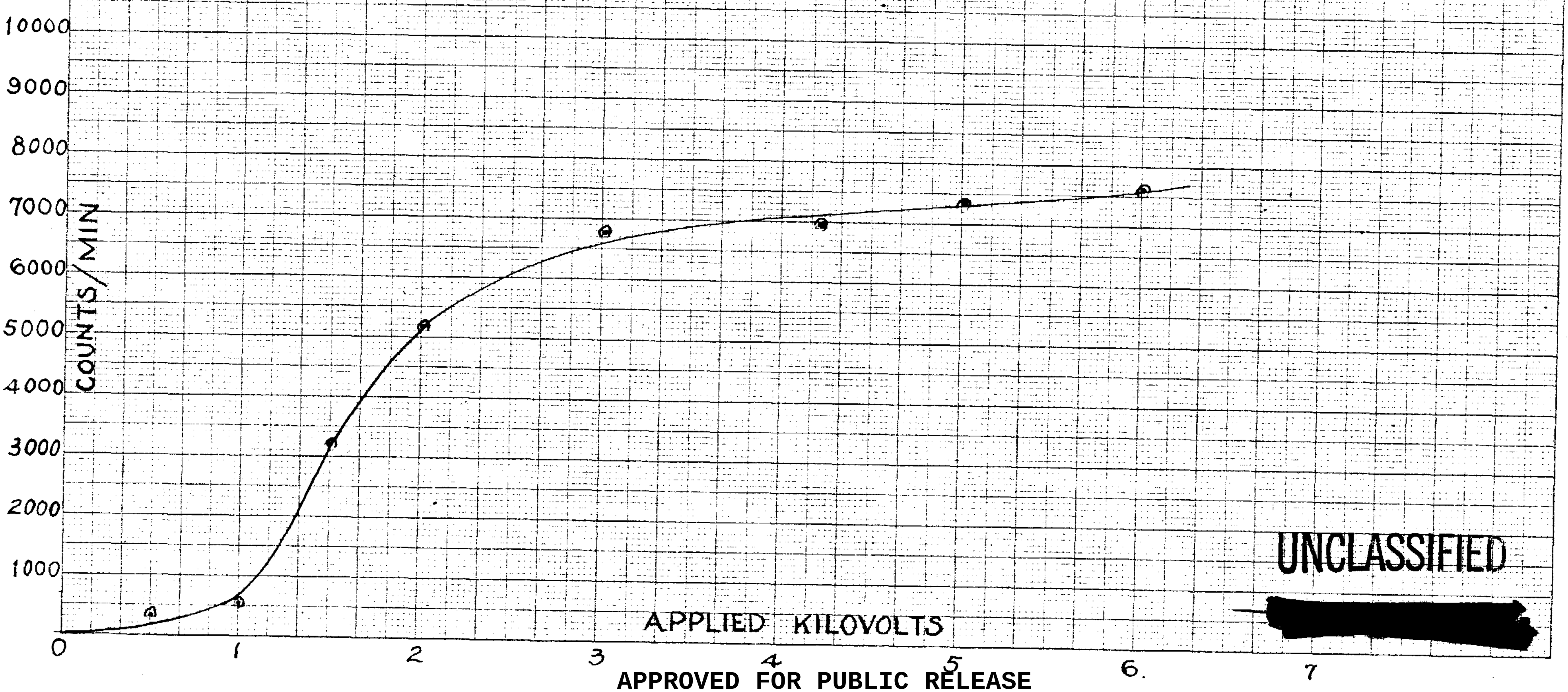
FIGURE 5

VOLTAGE CURVE
LARGE CHAMBER
SYNTHETIC BF_3: 74.6 cm Hg
CONSTANT BIAS: 80
CONSTANT SOURCE: Ra + Be No. 51



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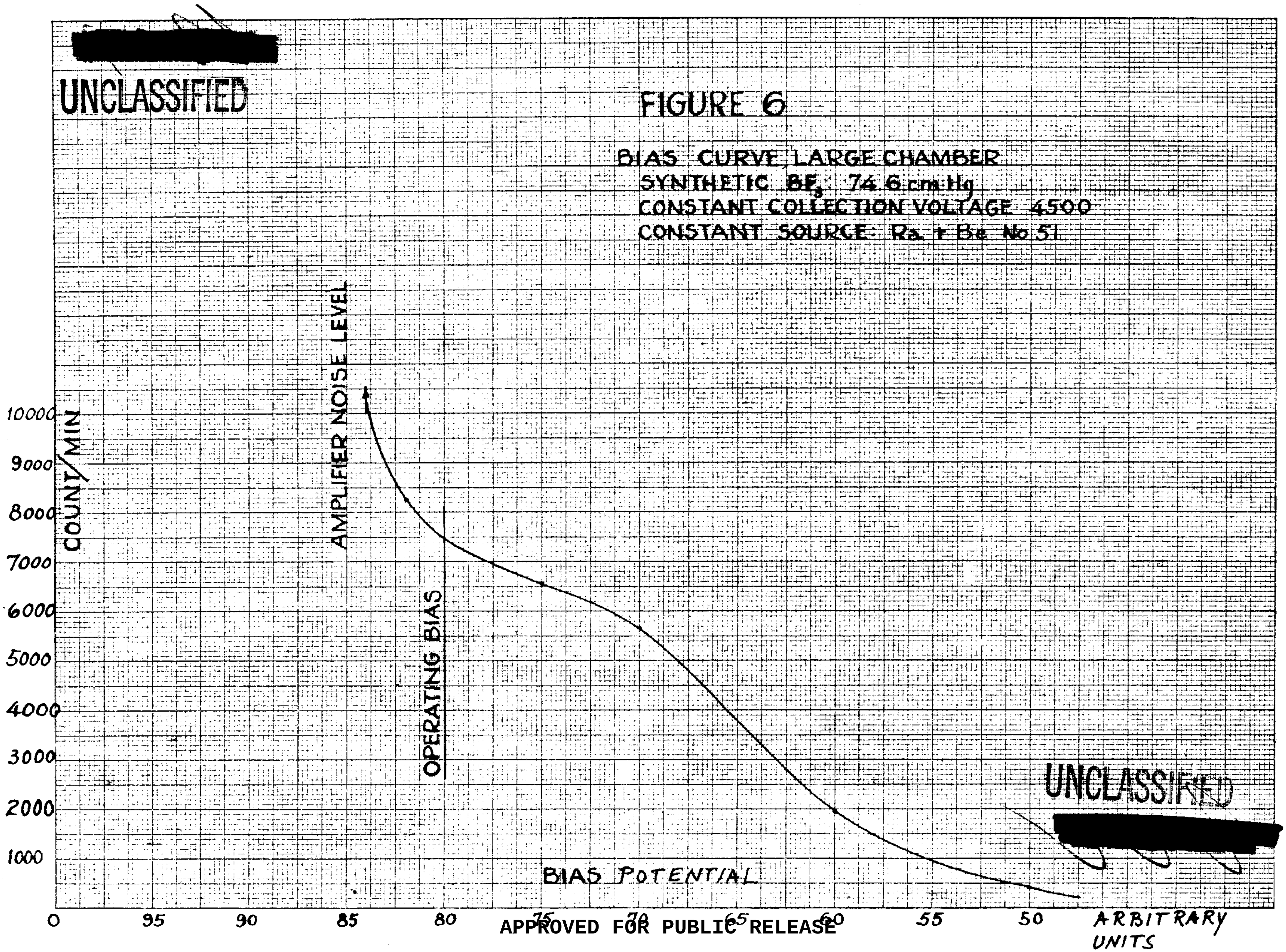
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FIGURE 6
BIAS CURVE LARGE CHAMBER
SYNTHETIC BF_3 74.6 cm Hg
CONSTANT COLLECTION VOLTAGE 4500
CONSTANT SOURCE: Ra + Be No. 51
AMPLIFIER NOISE LEVEL
OPERATING BIAS
COUNT/MIN
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
BIAS POTENTIAL
0
95
90
85
80
75
70
65
60
55
50
ARBITRARY UNITS
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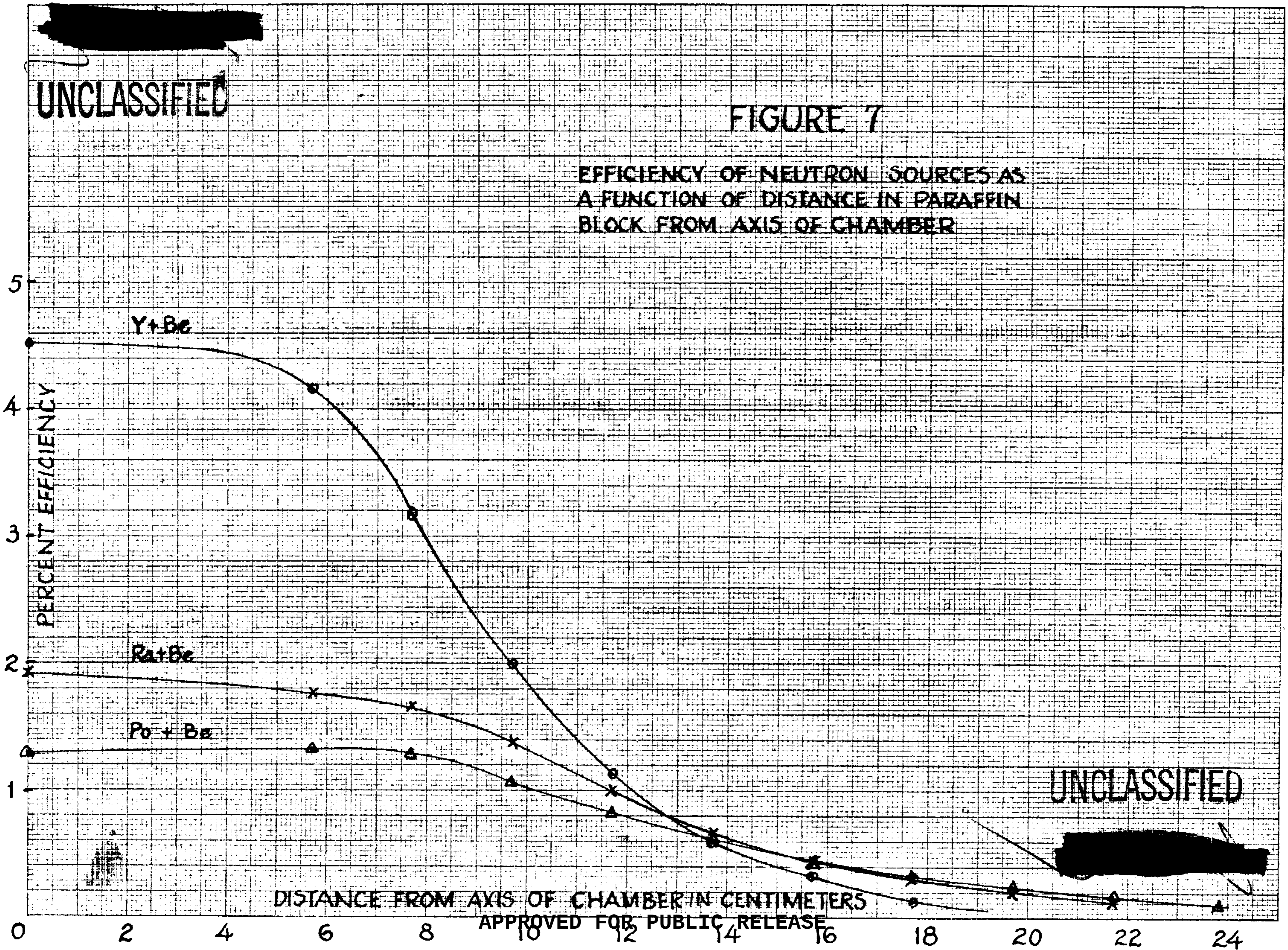
FIGURE 7



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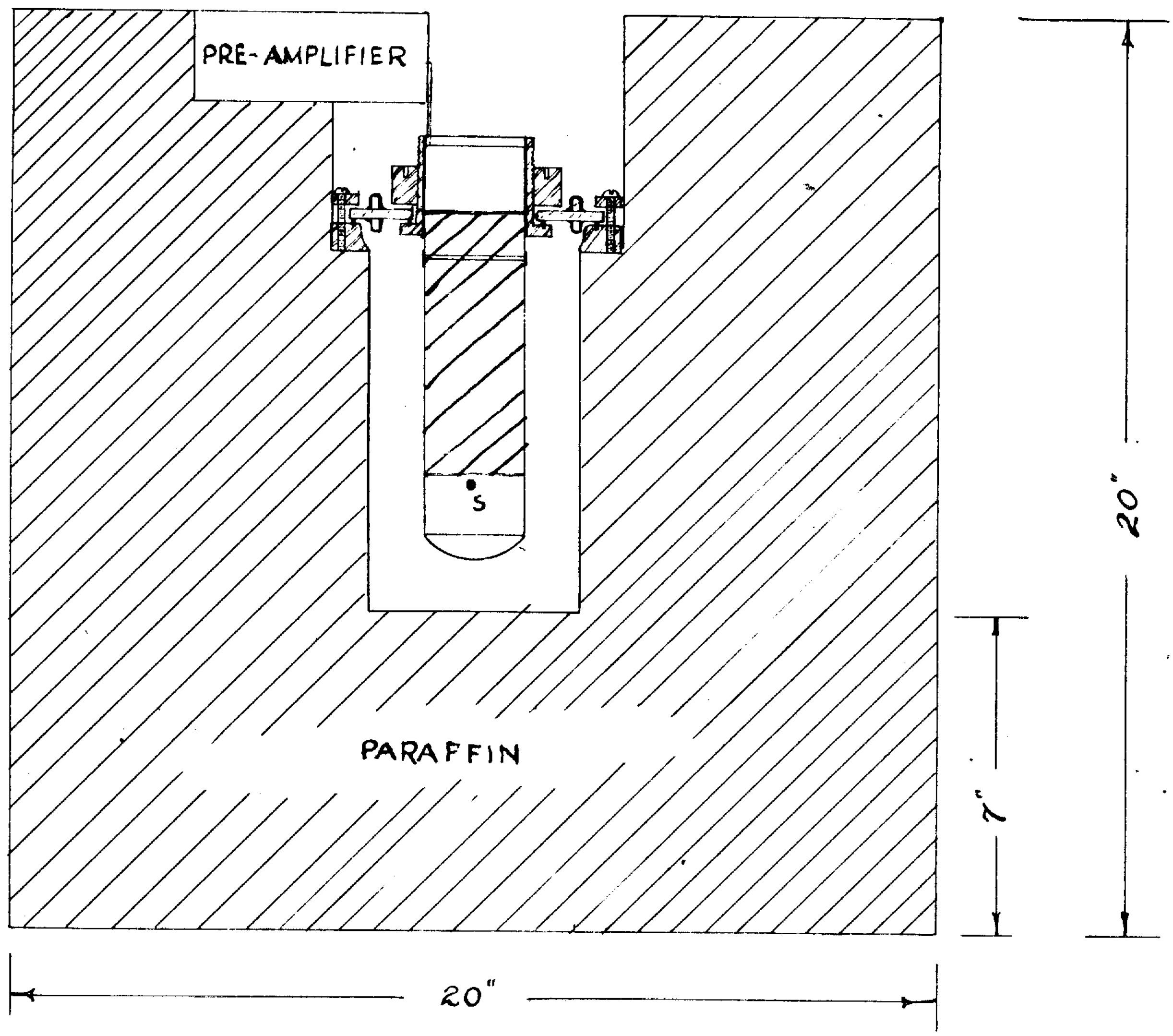

FIGURE 8

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